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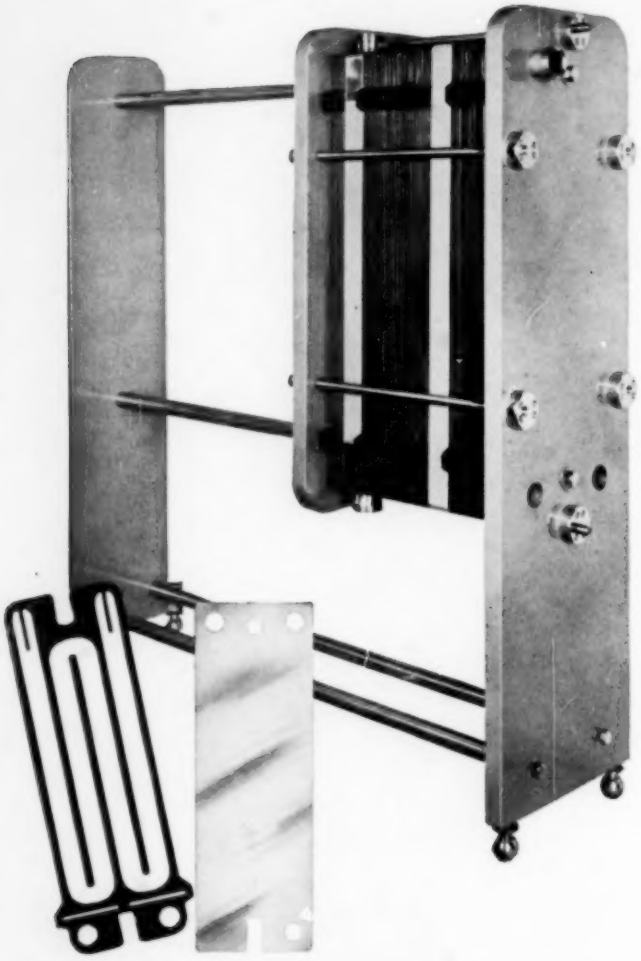

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Food Technology Curricula

This is the second of a series of articles which are intended to elucidate the basic ideas that govern the curricula of our educational institutions in the field of food technology. The author or authors of each article belong to the staff of a Department of Food Technology which is actively training students. It is planned to include an article from each educational institution offering a curriculum in food technology. The article will describe the philosophy which guides the course of study and will describe the contents of the course. Included in the series later will be a report by the IFT Committee on Education and Curriculum, based upon the results of a questionnaire which was recently submitted to members of the IFT.

Training the Food Technologist at Oregon State College

ERNEST H. WIEGAND[a] AND EARL M. LITWILLER[b]

The definition of FOOD TECHNOLOGY pinpoints the pattern for training the modern food technologist. It outlines most of the important considerations necessary to formulate a college curriculum for students:

> Food Technology is the technological application of science and engineering to the manufacture and handling of foods. Food technology is primarily based on the fundamentals of chemistry, physics, biology, and microbiology, any of which sciences may find expression through an engineering operation.
>
> Knowledge of food technology enables its possessor to develop new products, processes and equipment, to select proper raw materials, to understand and control food manufacturing operations, to solve technical problems of food manufacture and distribution, including those involved in plant sanitation, and those affecting the nutritional value and public health safety of foods and to know the fundamental changes of composition and of physical condition of foodstuffs which may occur during and subsequent to the industrial processing of foods.

This definition has been the guiding light for the basic courses in food technology curriculums—placing emphasis on the importance of science and engineering courses. Chemistry, physics, bacteriology, engineering, and related sciences have been the foundation on which the food technology curriculums were built.

However, there are great differences in the concept of *what* training is necessary for food technologists. These range from emphasis upon engineering to the strictly scientific aspects of chemistry and bacteriology. They include practical preparation as well as education for social living. As the term "technologist" implies an expert, the training has often been too narrow along certain lines to assure a well-rounded student program.

Any study of the evolution of curriculums in food technology would indicate many changes in philosophy. Since 1919 when the first courses in food technology were set up at Oregon State college, our curriculum has reflected these changes.

However, the professional schools of engineering and science undoubtedly influenced the early years of this development. Criticism of this philosophy indicated that education of the WHOLE MAN was neglected, that courses in the social sciences and the humanities could not fit into education for the professional student. Training for citizenship has been considered secondary to training to be an expert in a chosen field.

The curriculums today in many professional schools indidcate the trend towards consideration of the student as a member of a profession. The importance of getting along with people, no matter what position he fills, has influenced the trend towards more courses in the social sciences. That a student should understand the society in which he lives has become an important consideration in building a curriculum.

Construction of the new $850,000 food technology building at Oregon State was started in May, 1950. Plans call for one of the most modern buildings for instruction and research in the United States. The facilities and modern equipment will make possible many different types of food processing study.

The two story building, 168 feet by 208 feet, is a dream come true for this pioneer department in the training of food technologists. Its modern facilities which include many laboratories, a big pilot plant, an auditorium, and conference rooms represent more space for expanded activities of the department.

The first floor will be devoted entirely to under-graduate instruction and laboratory space. The second floor will house the graduate work and the agricultural experiment station. Special laboratories for different phases of research will provide facilities for greater study of food processing problems.

The needs of the food industry have influenced the curriculum to train food technologists. Even a cursory study of the membership list of the Institute of Food Technologists reveals the varied types of positions which food technologists occupy. These positions represent work through the gamut of food processing from field work to sales, distribution, and consumer education. Federal laboratories and agencies are employing more food technologists to handle different types of jobs. The economic problems incident to the operation of a food processing plant has created the need to add busi-

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[b] Professor of Food Technology.

ness courses to the curriculum. Understanding labor problems, personnel problems, and business law has pointed to the need to study along business administration lines.

Packaging, transportation, and handling problems of the industry have also pointed to the need for training in these fields. Related industries are coming to departments of food technology to hire men to work for their organizations. The education of the food technologist, thus, must be varied to fulfill many job requirements.

The extra-curricular activities program as set up in most colleges offers students unique opportunities for group leadership as well as for experience in getting along with people. Student advisors might well counsel their students to participate in the varied range of college activities. Here, on a smaller scale, arise the problems of modern day living. Although food technology clubs and student I. F. T. chapters offer leadership opportunities, the college association permits many different challenges to the student.

The food technology curriculum which does not allow time for participation in student activities might well be questioned. This matter of getting along with people is one which no director of a food technology training program can afford to overlook. The professional person, skilled as he may be, has less chance for success if he lacks the ability to work easily with people — his superiors, his equals, and his employees.

The curriculum at Oregon State College was first set up in 1919, pioneering in schools of higher education in the United States. It was governed primarily by the thinking of the school of agriculture. Slowly the required courses in agriculture which did not fit into the training of students in food technology were dropped. Replacing these were courses in the sciences upon which food technology is based. Such courses applicable to the field thus gave students the background needed for a basic understanding on which to build their knowledge of food technology.

This new department under the school of agriculture was the first to break away from the list of required agricultural subjects held necessary for students in that school. However, some of these essential courses are still required in the curriculum for students taking options in production.

"Curricular options" in the four year curriculum at Oregon State College represent a new trend in thinking. This philosophy allows students to direct their work towards definite phases of the food industries. Our curriculum for the first two years of college work is practically identical for all food technology students. During the junior and senior years each student may select an option in which he is most interested. These options give final emphasis to (1) INSPECTION AND CONTROL, (2) PRODUCTION, (3) ADMINISTRATION AND MARKETING, (4) RESEARCH AND GRADUATE STUDY, and (5) FOOD ENGINEERING.

The required courses for the first two years are those which our staff regard as providing the foundation stones for the five options. During the first two years the students are introduced to both the scientific and the cultural type of subject matter.

Freshman Year [c]

English Composition	3 terms, 9 credits
General Chemistry	3 terms, 9 credits
Intermediate Algebra	1 term, 4 credits
General Botany	2 terms, 6 credits
Elements of Horticulture	1 term, 3 credits
Food Plant Mechanics	3 terms, 6 credits
Extempore Speaking	1 term, 3 credits
Physical Education	3 terms, 3 credits
Military Training	3 terms, 6 credits

Sophomore Year

Principles of Food Preservation and Canning Fruits and Vegetables	2 terms, 6 credits
Nutrition	1 term, 3 credits
Organic and Agricultural Biochem.	2 terms, 8 credits
Abridged General Physics	2 terms, 6 credits
General Bacteriology	3 terms, 9 credits
Outlines of Economics	1 term, 3 credits
Modern Governments	1 term, 3 credits
Applied Psychology	1 term, 3 credits
Physical Education	3 terms, 3 credits
Military Science	3 terms, 6 credits

The following chart gives the detail course requirements for each of the five options. College requirements for graduation with a Bachelor of Science degree are: successful completion of 192 term hours which must consist of 36 hours in the major department of food technology, 36 hours in science or 45 hours in science and social science.

Suggested electives [d] include many of the courses required in the options; besides these are courses such as:

Pacific Area Relations	Democratic Traditions in Literature
Foundations of National Power	Industrial Traffic Management
Transportation	Colloidal Chemistry
Cooperative Marketing	Organic Chemistry

The philosophy of the under-graduate curriculum is that the student should not only be well trained in the basic sciences and in food processing methods, but also he should be exposed to a widely varied type of courses which will prepare him for his place as a member of society.

Graduate work in the food technology department at Oregon State leads to masters' and doctors' degrees. The course for each student is set up individually to fit his particular needs and interests. A research thesis is required for each degree. For the master's degree, twenty-one graduate credits in food technology in addition to the thesis are required, with minor work in biochemistry, horticulture, business administration, bacteriology, dairy technology, or related fields.

Some of the senior courses carry graduate credit. Other courses taught on a graduate level are: Food Industries Research Methods, Advanced Food Fermentations, Protein and Colloid Technology, Quality Control Systems, Fat and Oil Technology, Color and Flavor Evaluations, Pectin Technology, and Advanced Dehydration.

The curriculum at Oregon State College is not static,

[c] The college year includes 3 terms of work; 1 credit hour equals 3 class hours per week.

[d] An average of 27 credits of electives are allowed in each option.

Required Courses for Options In:	Inspection and Control	Production	Administration and Marketing	Research and Graduate Study	Food Engineering
Political Science (2 terms, 6 credits)	•	•	•	•	•
Food Technology (2 terms, 6 credits)	•	•	•	•	•
Industrial Food Fermentations (1 term, 3 credits)	•	•	•	•	•
Technology of Preserves and Jellies (1 term, 3 credits)	•	•			
Agricultural Chemical Technology (2 terms, 6 credits)	•			•	•
Principles of Agricultural Marketing (1 term, 3 credits)	•				
Principles of Economic Entomology (1 term, 3 credits)	•	•			
Vegetable Crops for Processing (1 term, 3 credits)	•	•			
Inspection of Processed Foods (1 term, 3 credits)	•	•			
Principles of Accounting (1 term, 3 credits)	•	•	•		•
Seminar (3 terms, 3 credits)	•	•	•	•	•
Frozen Foods (2 terms, 6 credits)	•	•	•	•	•
Regulatory Control of Food Products (1 term, 3 credits)	•	•		•	•
Food Processing Control Methods (2 terms, 6 credits)	•			•	
Principles of Plant Pathology (1 term, 4 credits)	•	•			
Methods of Research (1 term, 3 credits)	•			•	
Business Law (1 term, 3 credits)	•	•	•	•	
Human Relations in Business and Industry (1 term, 3 credits)	•				
Detection of Food Adulterants (1 term, 3 credits)	•				
Principles of Plant Physiology (1 term, 4 credits)		•		•	
Food Processing Plant and Equipment (1 term, 3 credits)		•			•
Refrigeration and Cold Storage (1 term, 3 credits)		•		•	
Work Simplification and Measurement—I and II (2 terms, 6 credits)		•			
Soils (2 terms, 6 credits)		•			
Fruit Handling and Distribution (1 term, 4 credits)		•			
Fruit and Nut Production (1 term, 4 credits)		•			
Human Relations in Business and Industry (1 term, 3 credits)		•	•		
Production (1 term, 4 credits)		•	•		
Dehydration of Foods (1 term, 3 credits)			•		
Technology of Beverages (1 term, 3 credits)			•		
Principles of Agricultural Marketing (1 term, 3 credits)			•		
Finance (1 term, 3 credits)			•		
Labor Problems (1 term, 4 credits)			•		
International Trade (1 term, 4 credits)			or •		
Credits and Collections (1 term, 3 credits)			•		
Personnel Management (1 term, 3 credits)			•		
Salesmanship (1 term, 3 credits)			•		
Elementary Analysis (3 terms, 12 credits)				•	
Applied Statistics (1 term, 3 credits)				•	
Chemical Technology (1 term, 2 credits)					•
Differential and Integral Calculus (3 terms, 14 credits)					•
Elementary Unit Operations (1 term, 3 credits)					•
Materials of Engineering (1 term, 3 credits)					•
Unit Operations (3 terms, 9 credits)					•
Elements of the Process Industries (3 terms, 9 credits)					•

but rather, it continually reflects the needs of industry for specially-trained men. It is geared to the demands of industry for men with scientific backgrounds who have the "know how" of the many phases of the food industries. The curriculum also reflects the demands of society for men who can be community leaders, who know and understand what is going on in the world. Its goal is to provide students with the opportunity to study many areas of the educational field which will better prepare them for life after graduation.

Reaction of Age Groups to Organoleptic Tests[a]

WILLIAM DOWELL BATEN[b]

(Received for publication, April 3, 1950)

The younger judges were more capable of distinguishing differences in different strengths of salty and sweet materials than middle-aged people. This was not true for sour material. Correlation should be determined before adequate tests of significance can be employed.

Introduction

Panels of judges testing food qualities often contain people of various age groups. Some research workers, experienced with carrying out organoleptic tests, believe that young people react differently to food stimuli than more mature people. The object of this paper is to present results of experiments designed to determine whether or not there were differences between decisions pertaining to foods made by college freshmen and people of middle age. Three types of foods were used in these experiments namely; salty, sweet, and sour materials. These materials were chosen because they represent three distinct types of foods which stimulate the taste buds for a considerable time after being taken into the mouth.

Faculty members, secretaries and freshmen at Michigan State College composed the panels for these tests. The average age of the freshmen was about 18 years; the average age of the other group was between 35 and 40 years. The same people did not take all of the tests.

All of the materials had been kept in a refrigerator for 2 hours before serving.

[a] Journal Article No. 779 (n.s.) from the Michigan Agricultural Experiment Station.

[b] Professor of Statistics, Michigan Agricultural Experiment Station and Michigan State College, East Lansing, Michigan.

Materials

Commercially canned tomato juice with and without added salt represented the salty materials; commercial apple juice containing about 12 percent of sugar and this same juice, with sugar added so that it contained about 20 percent of sugar, represented the sweet materials; lemonade containing 16 and 8 large lemons per gallon respectively, without added sweetening, constituted the sour materials. These tests were made on three afternoons, one afternoon for each type. Several of the tasters took all of the tests. Each judge was requested to record his or her decisions on the following score sheet:

Name of material..... Date.....

Taste the material and place a vertical mark across the line joining Very Poor and Excellent, where in your opinion the sample should be classified.

Sample.....

A Very Poor Excellent

B Very Poor Excellent

Name.....

Samples A and B consisted of different strengths; for example sample A for the tomato juice was ordinary tomato juice and sample B was the same juice with salt added. Sample B in this case was not too salty for the average person to relish, but was salty enough to be distinctly different from sample A. Some of the judges tasted the former first and some the latter first. This type of score sheet was chosen because it enabled the individual to make a contrast between the two strengths; for after scoring the first sample his or her score for the second sample was made in relation to the first score. This meant that the second score or mark on one of the horizontal lines on the score sheet was to be to the left, on, or to the right of the mark pertaining to the first sample. This caused the taster to think about both samples before making the second decision. The distance from Very Poor, or the zero end of the horizontal line, to the mark made by the taster was measured and recorded as the score of the individual for this sample. The score might have been any value from 0 to 6 as the horizontal lines were 6 inches long. The organoleptic tests were arranged so as to detect differences between two concentrations and differences between the age groups if there were any.

Results From the Salty Materials

The averages of the scores relating to the two strengths of tomato juice and their standard deviations are as follows:

Freshmen		Middle age group	
A	B	A	B
Ordinary	Salty	Ordinary	Salty
Ave. ± S. D.	Ave. ± S. D.	Ave. ± S. D.	Ave. ± S. D.
1.97 ± 0.22	3.12 ± 0.22	2.98 ± 0.27	3.62 ± 0.26

Thirty-five freshmen and 29 mature people participated in this experiment. There is no correlation between the scores on samples A and B for both groups; this shows that if a judge rates sample A high he or she did not consistently rate the second sample higher or lower. There is a significant difference between the averages of samples A and B for both age groups. The young people prefer ordinary tomato uice to the salty juice; the older people prefer the salty to the ordinary. There is a significant difference between these two differences. There is also a significant difference between the averages pertaining to ordinary tomato juice for these two age groups. The two sets of tasters are in agreement concerning the saltier material.

Results Pertaining to Apple Juice

Thirty-seven freshmen and 27 older people graded the two concentrations of apple juice. The averages of their scores are as follows:

Freshmen		Middle age group	
A	B	A	B
12% sugar	20% sugar	12% sugar	20% sugar
Ave. S. D.	Ave. S. D.	Ave. S. D.	Ave. S. D.
4.69 ± 0.14	3.47 ± 0.22	4.41 ± 0.23	3.70 ± 0.23

The students like the ordinary apple juice better than the juice containing 20 percent of sugar. There is a significant difference between the averages of the student scores but no significant difference between average scores of more mature judges; this shows that the young people distinguish a difference between these two strengths where the older people do not. There is no significant difference between the arithmetic means pertaining to the ordinary apple juice; this is also true for the sweetened juice. There is no correlation between the decisions about the first and second sample for either group. The results from these tests indicate that young people and more mature people judge sweet things about alike.

Results From the Sour Materials

Sixty-eight freshmen and 24 middle age people tasted these materials; the averages together with the standard deviations are listed below.

Freshmen		Middle age group	
16 lemons per gallon	8 lemons per gallon	16 lemons per gallon	8 lemons per gallon
Ave. S. D.	Ave. S. D.	Ave. S. D.	Ave. S. D.
1.53 ± 0.15	1.38 ± 0.12	2.05 ± 0.28	1.50 ± 0.24

There are no significant differences between the various averages within age groups and between age groups. This means that freshmen and more mature people rate the difference concentrations of these sour materials about alike. There is a significant correlation between the scores on samples A and B for both groups, meaning that the score given to the second sample is dependent upon that given to the first. As was stated above, this is not true for the salty and sweet materials. The young people are more consistent in their decisions pertaining to sour material than the older people, as can be seen by the sizes of the standard deviations.

Summary

This study has shown that—

1. Young and more mature people do not evaluate certain foods the same.

2. Young people distinguish differences between different strengths of materials when more mature people do not.

3. It is well to test for differences between age groups making up panels before drawing conclusions from the results.

4. There was correlation between the sour samples and not between the salty and sweet. Correlation must be considered when analyzing satisfactorily some data.

The pH and Total Acidity of Raw and Canned Pimientos[a]

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Department of Food Technology, University of Georgia, Athens, Georgia

(Received for publication, January 30, 1950)

The purpose of the study was to establish with adequate sampling the range and average pH of canned pimientos. The pH ranged between 4.6-5.3. The average pH was 4.95. The normal range of the red, raw product was 4.7-5.5; however, red pods exhibiting pH values as high as 5.9 were encountered. During growth the pH of the pod rises from an initial pH level of 5.3 to a maximum of approximately 6.3, then during coloring it falls eventually to a minimum of 4.7. The pH of green, mature pods ranged between 5.1-6.3. The application of these facts to the canning of pimientos is pointed out.

Outbreaks of spoilage occasionally plague the pimiento canning industry. Although pimientos packed in glass jars are processed above 212° F. (100° C.), pimientos packed in cans—by far the larger portion of the pack—are cooked at 212° F. (100° C.). Though most literature reports suggest that the pH of pimientos averages 4.7, some investigators have found the pH as high as 5.15 *(5)*. A preliminary survey of 1947-packed pimientos revealed that pH 5.15 is not the upper limit *(10)*.

When one considers that pimientos should perhaps be classified as a low acid food and that they are water processed, the fact that spoilage occurs could not only be of economic significance but also a public health warning. A two-pronged attack was therefore initiated to: (a) secure adequate, representative pH measurements basic to evaluating the problem and eventually solving it through bacteriologically derived, calculated processes and (b) develop practical acidification procedures as an immediate way to prevent additional spoilage.

Review of Literature

Relatively few pH values are reported in the literature. Bigelow and Cathcart *(1)* found the pH of lye-peeled and flame-roasted pimientos to be 5.1 and 4.7, respectively; the corresponding values for one can each of the canned product were 5.16 and 4.68. Bridges and Mattice *(3)* list the pH of pimientos as 4.65 based upon one sample. Values ranging from pH 4.3 to 4.9 with the average of 24 samples pH 4.7 are tabulated in *The Canned Food Reference Manual (9)*. Culpepper et al. *(5)* tested extensively several varieties of peppers. They reported the pH of canned pimiento pepper to range from 4.6-5.15. Heat penetration, pH, and acidification studies were conducted simultaneously with the study reported herein by Wessel and Roberts of the American Can Company. They have since reported the pH of raw pimientos to be 5.0-5.2 and the canned product 4.9-5.1 *(16)*.

Sane *(12)* has tabulated un-published values secured from the company files of some Georgia canners, from the National Canners Association, and the Continental Can Company *(2, 4, 11, 13, 14, 17)*. The values ranged from 4.4 to 5.5.

Three important facts thus become evident: (a) some of the reports are based upon such few samples that the data may not be representative, (b) the range of values (4.3-5.5) is suspiciously wide compared with most other plant materials *(9)*, and (c) the values fall within the low acid range sufficiently often to require further study inasmuch as water bath processing prevails.

Experimental

Pimiento samples were collected at bi-weekly intervals during the 1948 season, July 15 to December 6, from 41 growers apportioned among all Georgia growing areas. Analyses were made in five plants at each stage in the canning operation, from the coloration pile to the warehouse, to ascertain the effect of canning operations upon the pH. Each time field or plant samples were collected, canned samples were also secured.

The pH was determined with a Beckman model H pH meter. The total acidity, calculated as anhydrous citric acid, was measured by titrating electrometrically to pH 8.1 *(8)* with 0.1 N NaOH. The buffering capacity was calculated according to Van Slyke *(15)* between pH 5.3-6.3.

Each fresh sample consisted of four pods chosen at random from about one peck which in turn had been picked at random throughout the field. Statistical analysis of several series of four-pod samples gathered from a coloration pile indicated that the mean of duplicate four-pod samples would reduce pH and total acidity

[a] A portion of a thesis submitted to the Graduate Faculty of the University of Georgia by Miss Ruth H. Sane in partial fulfillment of the requirements for the degree, Master of Science in Agriculture.

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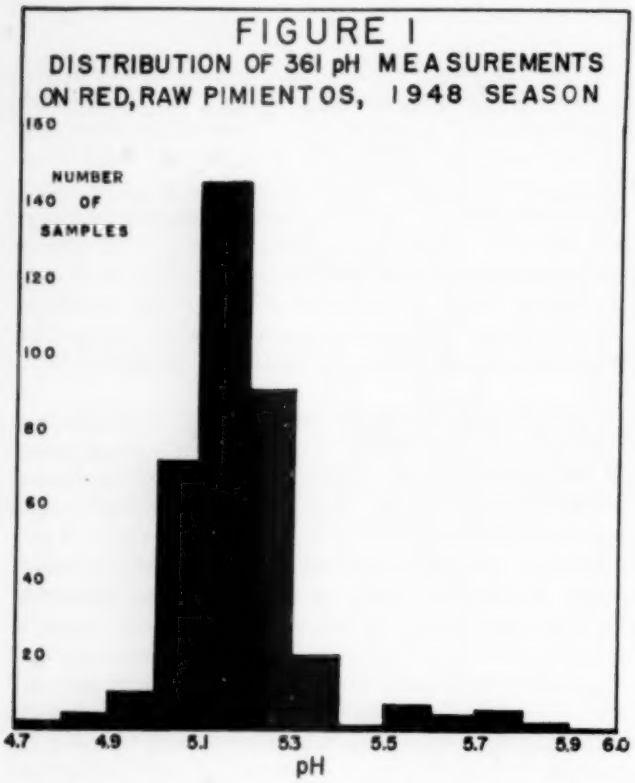
sampling variation to a reasonable level. The fresh samples were prepared by coring and cutting the pods into small pieces. After mixing, 100 grams of cut pimiento were pureed with 100 ml. of distilled water. Initial study established that the pH of samples prepared with and without added water to facilitate blending never differed by more than 0.05 pH units. The canned samples were pureed without added water.

Results

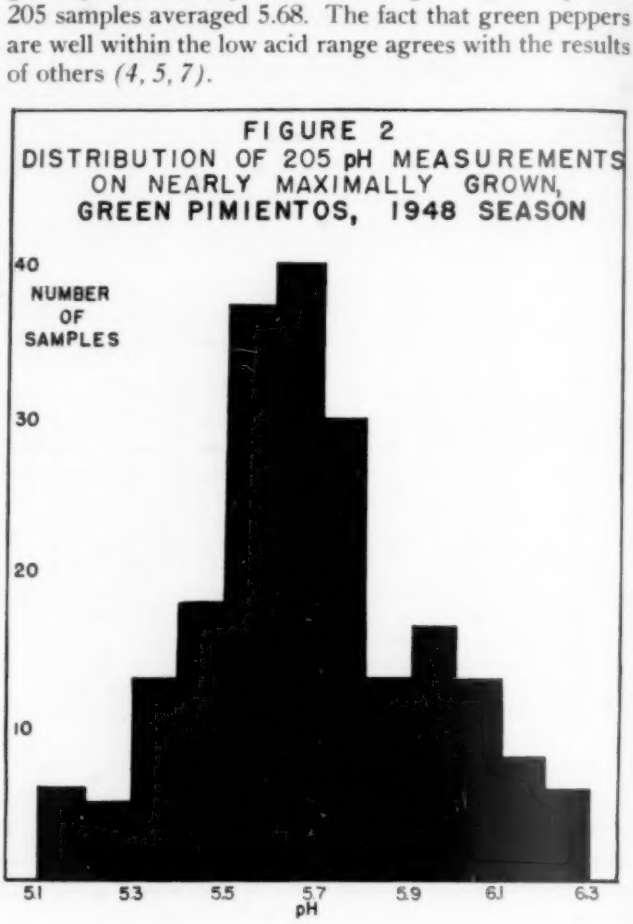
The pH of Raw Pimientos. The pH of red, raw pimientos was generally above 5.0 during the 1948 season. A histogram of the 361 measurements may be seen in Figure 1. The pH averaged 5.18. Approximately



94% of the values fell within the pH interval 4.86-5.50. Normal sampling variation acounts, no doubt, for most of the extreme variation; however, at least one other factor contributes to the extreme deviation above the average. The pH sequence through which pimientos go during maturation is that factor.

Whenever red pods were collected, green pods at various stages of maturity were also collected. Immature or small pods were generally close to pH 5.3. As the pod increased in size, the pH rose to a maximum of 6.3. By the time initial color formation occurred, the pH was between 6.0-5.1. During growth the pH thus rose from an initial level of about 5.3 to a maximum of 6.3, then decreased eventually to a minimum of 4.7 for red pods. Cochran *(4)* investigated the pH sequence in greater detail in that he started measurements at the unopened bud stage. His observations were similar except that he found maxima of 6.3 to 6.95 and he did not observe color formation until the pH decreased to 5.0. The latter finding is in contrast to our results and those of Wessel and Roberts *(16)*.

The distribution of the pH measurements made upon green pimientos may be seen in Figure 2. The pH of 205 samples averaged 5.68. The fact that green peppers are well within the low acid range agrees with the results of others *(4, 5, 7)*.



The relationship between pod maturity and pH is important to the canner. It may explain why a few canned red pimientos showing pH values as high as 5.5 have been encountered *(2, 10)*. Although the canners grade out partially- or under-colored pods at the receiving platform, light red pods are sometimes accepted for the standard grade or sliced pimientos. When they are, the pH is high. Particular attention should then be paid to processing because of the well known fact that the thermal resistance of many organisms increases with increasing pH. In nearly all cases, however, the pH of good grade canning pimientos will be below 5.3. The highest found in the coloration piles was 5.32.

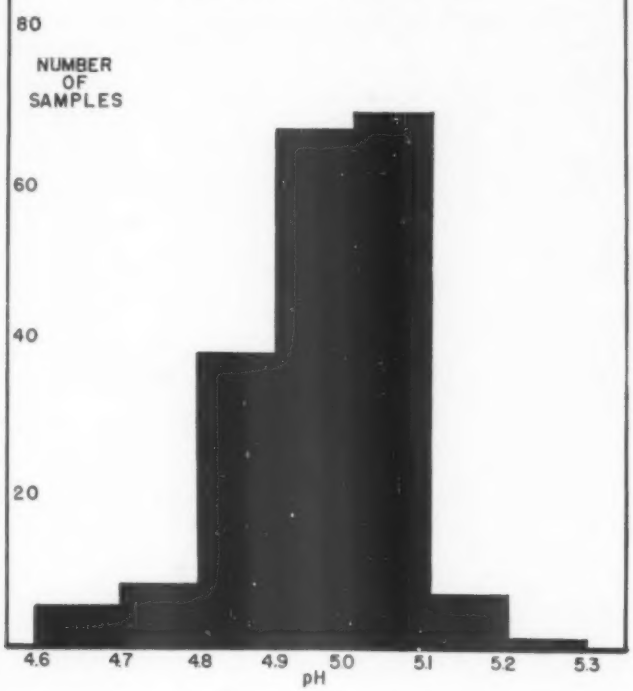
No variable other than maturity was found to affect significantly the pH of pimientos. Efforts were made to correlate the pH with variety, geographical growing location, and fertilization treatment, but no correlation was discernible. There was however a slight tendency for the pH to decrease as the season advanced. Perhaps a greater number of samples or a different year would have clearly demonstrated such a trend. Woerz *(17)* has observed a season decrease; and the industry sometimes decreases processing times slightly as the season progresses.

Effect of Canning on pH. The field phase of the study having shown that raw pimientos should be classified as a low acid product, 127 determinations were made in five plants at five stages of canning to ascertain whether

ordinary plant operations produced significant pH changes. During roasting, cooling and washing after roasting, blanching, cooling after blanching, and exhausting, the pH progressively decreased from pH 5.18 at the coloration pile to 5.00 immediately preceding processing. During processing, the pH dropped an additional 0.1 unit. Application of Student's "t" test between values at the coloration pile and immediately after processing demonstrated a highly significant statistical difference. Coincidentally, the field and coloration pile samples averaged pH 5.18.

pH of the Canned Product. The difference between the pH of the raw pimientos and 195 samples of 1948-packed pimientos also showed that canning causes a decrease in pH. The average of the canned product was 4.95. Approximately 95% of the values came within the range, 4.75-5.15, as may be seen in Figure 3. The average agreed well with those of other recent investigators *(4, 5, 11, 16, 17)*.

FIGURE 3
DISTRIBUTION OF 195 pH MEASUREMENTS ON 1948-PACKED, NON-ACIDIFIED, GEORGIA PIMIENTOS



To secure data relative to other packing seasons, cans were secured from canners for seasons prior to 1948. The average pH of 24 cans of 1947-packed pimientos was 4.94. The range was from 4.78 to 5.50. Only one to four cans were available for each year in the period 1934-46. Of these the lowest pH was 4.56 and the highest 4.85. The average was 4.75. Some of the cans examined may have been acidified because packing records were not complete.

Total Acidity and Buffering Capacity. The total acidity of 333 red, raw pimiento samples averaged 0.28%, calculated as anhydrous citric acid. The standard deviation was 0.067. The corresponding values for 203 samples of green pimientos were 0.16% and 0.042. The total acidity of 127 cans of pimientos averaged 0.17%.

The buffering capacity of 293 samples of red pimientos averaged 7.15 with a standard deviation of 1.68. The corresponding values for 204 samples of green pimientos were 3.18 and 1.02.

A highly significant statistical difference existed in each case between the pH, total acidity, and buffering capacity of the red and green, raw pimientos.

When the pH and the total acidity of all the red and green pimientos was plotted as a scatter diagram on semi-logarithmic paper, a linear relationship appeared to exist. Because factors other than the total amount of acid present could affect the pH, a linear regression equation was not derived. The correlation coefficient between the hydrogen ion concentration and the total acidity for 547 pairs was 0.905. This, according to Hoel *(6)*, would indicate that the total acidity represented above 82% of the factors determining the pH.

Summary

1. The pH and total acidity of red, raw pimiento peppers averaged, respectively, 5.18 and 0.28%.

2. The respective values for green pimientos were 5.68 and 0.16%.

3. The initial pH level of small, immature green peppers was about 5.3. As the pods enlarged, the pH increased to a maximum of 6.3. As they ripened, the pH fell to a minimum of 4.7.

4. Canning produced a statistically demonstrable decrease in pH.

5. Approximately 95% of 1948-packed pimientos examined exhibited pH values between 4.75-5.15. The average was 4.95.

Conclusions

The pH of canned pimientos may be expected to average approximately 4.95 with a range of 4.6 to 5.3. Unless fully colored pods are canned, the pH may be as high as 5.5 because color formation may be appreciable before the pH falls markedly from the maximum. As the color becomes a deeper red, the pH decreases. Pimientos of good canning color are between pH 4.7-5.3.

Acknowledgments

The authors acknowledge with pleasure the financial support of the Georgia Canners Association and the unstinted cooperation of individual canners in arranging for and collecting some samples and in placing their plants at our disposal.

LITERATURE CITATIONS

1. Bigelow, W. D., and Cathcart, P. H. Relation of processing to the acidity of canned foods. National Canners Association *Bull.* 17-L, 3 (1921).
2. Bloodworth, G. E. Personal communication (1948). Cherokee Products Co., Haddock, Georgia.
3. Bridges, Milton A., and Mattice, Marjorie R. *Food and Beverage Analyses*, 2nd Ed. (1942), Lea and Tebiger Co., Philadelphia, Pa.
4. Cochran, H. L. An address presented before the Georgia Canners Association annual meeting (1948). Pomona Products Co., Griffin, Georgia.
5. Culpepper, Charles W., Caldwell, Joseph S., Boyce, D., Wilcox, Marguerite S., and Hutchins, Margaret C.

The utilization of sweet peppers. Canning. *Fruit Products Journal* **24** (5), 132 (1948).

6. Hoel, Paul G. *Introduction to mathematical statistics,* 1st Ed. (1947). John Wiley & Sons, Inc., New York.
7. Lantz, Edith M. Effect of canning and drying on the carotene and ascorbic content of chili. New Mexico Agr. Expt. Sta. *Bull* **327**, 5 (1946).
8. Lepper, Henry A. *Official and tentative methods of analysis of the A.O.A.C.* 6th Ed. (1945). Assoc. Off. Agr. Chemists, Washington, D. C.
9. Pilcher, R. W. et al. *The canned food reference manual,* 3rd Ed. (1947). The American Can Company, New York 17, N. Y.
10. Powers, John J. Unpublished data (1947).
11. Reed, James M. Personal communication to John J. Powers (1948). National Canners Association, Washington, D. C.
12. Sane, Ruth H. The pH of fresh and canned pimientos and the effect of acidification upon the color, flavor, and texture of the canned products. *Thesis* submitted to the Graduate Faculty of the University of Georgia, 62 pp. (1949).
13. Shumaker, Fred. Personal communication (1948). Continental Canning Co., Macon, Georgia.
14. Speirs, Mary. Personal communication to H. L. Cochran (1948). Georgia Agr. Expt. Sta., Experiment, Ga.
15. Van Slyke, Donald D. On the measurement of buffer values and the relationship to the dissociation constant of the buffer and the concentration and reaction of the buffer solution. *J. Biol. Chem.* **52**, 525 (1922).
16. Wessel, D. J., and Roberts, H. L. Processing studies on pimientos. *Southern Canner and Packer* **10**, 4 (1949).
17. Woerz, John A. Personal communication (1948). Continental Can Co., Tampa, Fla.

Scoring Techniques for Sulfited Foods[a]

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This study was undertaken to determine the reason for erratic results encountered in the taste-panel scoring of sulfited foods. Tasters scored mashed potatoes containing 12 to 100 ppm. of sulfur dioxide. It was found that the first sulfite sample tasted dulled acuity of the taster for a subsequent sample containing the same amount of sulfite, but it had no influence on the score for a subsequent unsulfited sample under the conditions of the test.

We have known for several years that tasters at the Western Regional Research Laboratory who are usually reliable are erratic when they score sulfited foods. Their scores on sulfited replicates vary more than those for other foods. Correlation of scores with chemical results for a series of samples with different amounts of sulfite is poor. Tasters have even indicated presence of sulfite when none has been added; only, however, when a sulfited sample has been tasted shortly before the unsulfited material.

It has seemed obvious that sulfite has some unusual effects on tasters. The present study was undertaken, therefore, for the purpose of studying these effects under standardized conditions. It was planned to answer two specific questions regarding mashed potatoes to which sodium bisulfite had been added: (a) Does the first sulfited sample tasted dull acuity for a subsequent sample containing the same amount of sulfite? (b) Does the sulfite linger in the mouth and give the impression that it is present in unsulfited material tasted later in the same session?

Literature

Reports regarding the amounts of sulfite that can or cannot be detected by tasters differ considerably. Much of the variation is due, no doubt, to the food being tested, the sulfur compound and chemical method used, and, as the present study will show, to the judges and procedures used in the taste tests.

The following investigators report that concentrations of 20 to 90 p.p.m. of sulfur dioxide in various foods are *not* detected by tasters: MacArthur *(3)*, 40 to 90 p.p.m. of sulfur dioxide from several sources in frozen apples; Woodroof and Cecil *(6)*, 25 p.p.m. for any vegetable, 60 p.p.m. for tomatoes and rhubarb, 70 p.p.m. for most jellies and jams; Weast *(5)*, 20 to 40 p.p.m. in apricot jam; Green et al. *(1)*, 30 to 60 p.p.m. in cooked dehydrated potatoes.

Hohl and Swanburg *(2)* found that levels above 75 p.p.m. in frozen apricots were detected. Experience at this Laboratory (unpublished) indicates that 25 to 75 p.p.m. in uncooked fruits and vegetables is detected in the cooked products by trained tasters. The amount varies with the food and, of course, with individuals. Apricots can tolerate a higher level than apples or peaches, and the latter higher than potatoes.

Stadtman et al. *(4)* reported that their tasters showed no preference among cooked dehydrated carrot samples that varied from 2,000 to 15,000 p.p.m. prior to rehydration. They concluded that "their judges were, on the average, indifferent to sulfur dioxide level." Green et al. *(1)*, in referring to the wide range of scores for cooked dehydrated potatoes containing approximately the same amount of sulfur dioxide, concluded that while the presence of sulfur dioxide is readily determined by taste, estimates of the amounts present based on the apparent intensity of its "taste" are subject to very large errors. They also reported that a given amount of residual sulfur dioxide from sulfurous acid dips was more objectionable than that from sodium sulfite.

Selection of Judges

Following training of 26 persons from our Laboratory personnel, 10 members were selected for the sulfite panel. Only 6 of the trainees had served on any panel.

Solutions of sodium bisulfite were used in the first tests with trainees. Judges first tasted a sample which they knew was distilled water only, then two coded samples, one of water and one of water containing bisulfite. They were asked to identify the sulfited samples. Three replications of 25, 50, and 75 p.p.m. and one with 100

[a] Report of a study in which certain phases were carried on under the Research and Marketing Act of 1946.

[b] Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture.

p.p.m. solutions were tasted (concentrations were calculated as p.p.m. of sulfur dioxide). Following the work with solutions, judges were tested by the same procedure with sulfited mashed potatoes. Three replications of 50 and 75 p.p.m. and two with 150 p.p.m. were tasted. Sodium bisulfite solution was added to the potatoes just prior to mashing.

On the basis of results for the 18 tests, 10 of the 26 persons were selected for the panel. Seven identified all of the sulfited solutions and potatoes they tasted, and the other three failed on no more than three tests. Two experienced sulfite tasters who did not take the tests were included on the panel, giving a total of 12 persons.

Two persons who were not suitable for panel work are of special interest. One appeared to be blind to sulfite in solution and was dropped from the panel before the potato trials were made. Another was a good sulfite taster with solutions but failed completely with sulfited potatoes. Since both of these men were conscientious judges and capable members of panels for other foods, they were tested with higher concentrations of sulfite in potatoes. Concentrations of 500, 1000, 2000, and 5000 p.p.m. were tested on different days and in this order. One man first detected sulfite with 2000 p.p.m. and the other with 5000 p.p.m.

Experimental Procedure and Results

Russet Burbank potatoes were peeled, and a longitudinal quarter of each potato was used in each sample for one day's test. The potatoes were steamed for 25 minutes and a solution of sodium bisulfite was added just before the potatoes were mashed. The solution was made up with distilled water not more than two hours before the taste trials. Usually the coded samples for one day consisted of two sulfited samples of equal concentration and one unsulfited sample but in a few instances, for control purposes, the duplicates were the unsulfited material. Duplicates in either case were mixed before being served to the judges. In addition to the coded samples, a sample was included each day that judges knew contained no sulfite.

The potatoes were scored on a scale of 7, score 7 indicating no sulfite, and score 1 much sulfite. Scores were analyzed by the variance procedure, and if the F value was significant the smallest difference required for significance was calculated. Mean values from each day's test were the scores analyzed. Unless exception is mentioned, "difference" throughout this paper refers to significance at the 1 percent level or better. This means that the variability of the replicates was small enough that the observed differences between different samples almost certainly represents a real difference.

Some techniques that are not specified in most of our tasting work were included in this study in order to minimize and standardize the effect of the first sulfited sample tasted on scores for samples tasted later in the same period. Known unsulfited mashed potato was tasted before each unknown sample in the test. Judges rested one-half minute between unknowns. Each unknown was tasted only once. Samples were always tasted in the order submitted.

The samples for the first three tests were:

(1) One unsulfited sample and two containing 100 p.p.m. each of added sulfur dioxide,

(2) One unsulfited sample and two containing 50 p.p.m. each of added sulfur dioxide,

(3) Two unsulfited samples and one containing 50 p.p.m. of added sulfur dioxide.

Each of the three possible orders of tasting the three samples of one test was scored four times and the average of the four replicates are reported in Table 1.

TABLE 1

Influence of Order of Tasting Sulfited Potatoes

Test	Sulfur dioxide	Order of Tasting	Average Scores [a] for		
			Unsulfited sample or samples	Sulfited sample tasted first	Sulfited sample tasted second
	p.p.m.				
1	100	no sulfite, sulfite, sulfite	7.0	3.2	4.8
	100	sulfite, no sulfite, sulfite	7.0	2.8	5.0
	100	sulfite, sulfite, no sulfite	6.9	2.6	4.9
2	50	no sulfite, sulfite, sulfite	6.6	3.4	5.4
	50	sulfite, no sulfite, sulfite	6.9	3.4	5.2
	50	sulfite, sulfite, no sulfite	6.8	4.0	5.8
3	50	no sulfiite, no sulfite, sulfite	6.6 6.9	3.5	....
	50	no sulfite, sulfite, no sulfite	6.6 6.7	4.0	....
	50	sulfite, no sulfite, no sulfite	6.8 6.8	3.7	....

[a] Score 7 indicates no sulfite flavor, score 1 much sulfite flavor.

Order of tasting samples of a given test (Table 1) is concerned with 2 factors. The first factor is the influence of tasting the *unsulfited* sample on scores for any one of the samples. This is obtained by comparing scores in any one column of the table. The first and second sulfite samples tasted are considered as separate samples although they contain the same amount of sulfite. The other factor is the influence of tasting the *first sulfite* sample on the score for the unsulfited sample and also on the sulfite sample tasted later. This is obtained by comparing scores in one line of the table.

Tasting the *unsulfited* sample in first, second, or third position had no significant influence on the score of any sample. The F values for columns in tests 1, 2, and 3 were 0.42, 2.31, and 0.40 respectively, all of which are considerably below the value required for significance at the 5 percent level.

It was expected from previous work that judges would often indicate presence of sulfite in unsulfited samples if they were tasted after sulfited samples. This did not occur to a significant extent in the present study, however, probably because of the labeled unsulfited potato tasted between unknowns or the half minute rest periods. It should be noted that judges knew nothing about the samples except that effect of sulfite was being studied. In fact, days with one or two sulfited samples and different orders of tasting samples were randomized in order to conceal the pattern of the study from judges.

The first sulfite sample tasted (tests 1 and 2) received significantly lower scores than the second sulfited sample tasted, although the two contained the same amount of sulfite. Thus following tasting of one portion of sulfited potato, acuity of judges was dulled for a subse-

quent sulfited sample. This effect cannot readily be removed by a rinsing procedure, because when order of tasting was sulfited, no sulfite, sulfite, three portions of unsulfited material were tasted between the two sulfited samples.

One naturally wonders whether the difference between scores for the two sulfited samples is due to fatigue from too many samples in one taste session. The duplicate unsulfited samples of test 3 indicate that this is not the case. An additional trial with 2 unsulfited samples and one sulfited sample containing 100 p.p.m. of sulfur dioxide also showed this result. Scores for no sulfite, no sulfite, 100 p.p.m. sulfite were 7.0, 6.8, and 2.8 respectively. The plan in the additional test was like test 3 except that there were only 4 replications altogether (randomized order) instead of 4 replications of each order of tasting samples. Thus 3 samples do not seem too many for one session unless 2 of them are sulfited. Apparently the fatigue is a specific effect of a sulfited sample for another sulfited sample. It is likely that tasting of any food decreases acuity, that the amount of decrease varies with different foods, and that the response is very pronounced in the case of sulfited food.

The large dulling effect of a small portion of mildly sulfited food on tasters was considered of sufficient interest to justify investigation of lower concentrations of sulfite.

The samples for the additional tests were:

(1) One unsulfited sample and two containing 12 p.p.m. each of added sulfur dioxide,
(2) One unsulfited sample and two containing 25 p.p.m. each of added sulfur dioxide.

Six replications of each test were made and each of the three possible orders was submitted twice. The results for these tests, together with relevant data from Table 1, are summarized in Figure 1.

Statistical analysis of data from which Figure 1 was produced shows that decreased sensitivity of judges to sulfite following tasting of one portion of sulfited potato occurs when only 12 or 25 p.p.m. of sulfite are used as well as with the higher concentrations reported in Table 1. The difference between scores of the two sulfited samples in the 12 p.p.m. test was significant at the 5 percent level only but in all other tests significance was at the 1 percent level or better. The differences between the control and the first sulfited sample also were highly significant in all tests.

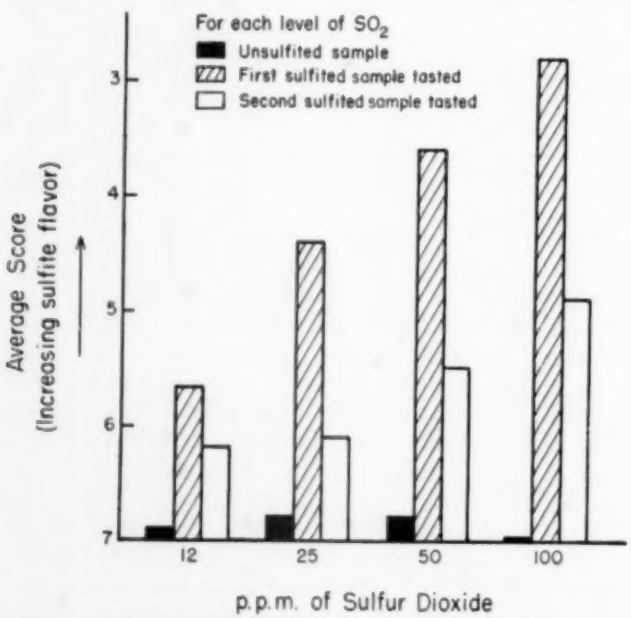

FIG. 1. Average Score versus Concentration of Sulfur Dioxide, at four levels of SO_2.

An estimate of the amount of dulling of acuity that occurs can be obtained from Figure 1. The second 100 p.p.m. sample tasted is about equal to a first sample containing 12 to 25 p.p.m. of sulfur dioxide. It is not surprising in view of these findings that the literature shows wide variation in the amount of sulfite detected by judges.

The necessity of scoring only one sulfited sample per judging session should not present a serious problem in most studies. The usual experimental procedure is to determine the minimum amount of sulfite that protects color and then to determine whether this one concentration gives an objectionable flavor. If there is sufficient need for evaluating a series of sulfited samples, however, a technique no doubt could be developed to meet this need.

Summary and Recommendation

Judges scored the strength of sulfite flavor in mashed potatoes to which 12, 25, 50 and 100 p.p.m. of sulfur dioxide (added as sodium bisulfite) had been added. Usually two samples containing the same amount of sulfite and one unsulfited sample were scored in one judging period. The results show that (a) tasting one portion of potato containing 12 to 100 p.p.m. of sulfur dioxide dulled acuity of tasters so much that subsequently tasted samples with the same amount of sulfur dioxide were rated as containing significantly less sulfite than the first sample, even when three portions of unsulfited material were eaten between the sulfited samples, and (b) by the techniques of tasting described here judges did not indicate presence of sulfite in unsulfited samples following sulfited samples although by earlier techniques this did occur.

It is recommended that until some new technique for evaluating flavor in a series of sulfited samples is shown to be reliable, that investigators evaluate only one sulfited sample per judging session.

LITERATURE CITED

1. GREEN, EDMUND L., CULPEPPER, C. W., CALDWELL, J. S., AND HUTCHINS, MARGARET C. The use of sulfur dioxide in dehydration of Eastern potatoes and other vegetables. *Fruit Products J.* **26**: (2) : 39-44; (3) : 81-6 (1946).
2. HOHL, LEONORA A., AND SWANBURG, JOYCE. Freezing of California fruits—apricots. *Food Packer* **27**: (4) : 37-8, 68, 70, 72 (1946).
3. MACARTHUR, MARY. Freezing apples for bakers—further investigations. *Can. Food Packer* **16**: (8) : 13-14 (1945).
4. STADTMAN, E. R., BARKER, H. H., MRAK, E. M., AND MACKINNEY, G. Storage of dried fruit. Influence of moisture and sulfur dioxide on deterioration of apricots. *Ind. Eng. Chem.* **38**: 99-104 (1946).
5. WEAST, C. A. Barreling of fruit for use in jams and preserves. *Canner* **100**: (25) : 34, 36, 38 (1945).
6. WOODROOF, J. G., AND CECIL, S. R. Sulfur dioxide solution as a preservative for fruits and vegetables. Ga. Expt. Sta. *Bull.* 238 (1945). 32 pp.

Blueberry Juice

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Analyses on samples of Maine and Florida blueberry juices prepared by cooking and draining, pressing, and Pectinol treatment are reported. Results of analyses on the Maine blueberry juice indicate an absence of any tartaric acid. Data on juice yields from Maine blueberries untreated and treated with Pectinol are included.

Blueberry (*Vaccinium angustifolium* Ait.) juice has been studied at the University of Maine for several years. These studies indicate that the specific gravity of blueberry juice produced from Maine blueberries is usually between 1.04 and 1.05, varying between these limits from year to year. Blueberry juice contains 90 percent moisture and 10 percent solids. One tenth to one fourth of the solids may be removed by centrifuging. Tressler et al. *(6)* suggested bottling juice for two months and then siphoning off the clear liquid.

The yield of juice obtained from blueberries varies from 50 to 88 percent by weight, depending upon the amount of pressure used. The berries may be cooked and pressed, or the fresh berries may be macerated and treated with 0.1 percent of pectinol M for two hours at 65-70° F. before pressing. The juice from berries treated with pectinol M is less viscous and has little or no sediment. The percentage yield of juice with different pressures is shown in Figure 1. One bushel of blueberries will yield about 4 gallons of juice (3.86 gallons on a weighed bushel, 42 pounds, and 4.13 gallons on a volume bushel, usually 45 pounds).

Analysis of the juice from Maine berries, Table 1, showed practically no difference regardless of the method by which it is obtained. The non-reducing sugars, which were a little higher in the commercial juice, may show the effect of time of harvest, since commercial berries were harvested later than the experimental berries. Chatfield and McLaughlin *(1)* found 12.4 percent sugar in blueberry juice. The comercial juice from Florida blueberries (probably *V. ashei* Reade) had a lower specific gravity, less reducing sugars and more non-reducing sugars than the juice from Maine blueberries. The color of the Maine cooked experimental juice which was packed in glass was a deep violet or purple. This pigment was so concentrated that it was opaque or nearly so in a layer three to four inches thick. The commercial juice which was prepared in the same way had the deep blue color characteristic of the tin salt of the pigment. The commercial juice was packed in enamel-lined cans, but the enamel is frequently scratched, permitting a reaction between the tin of the can and the pigment present in the juice. The juice from the berries treated with pectinol was red and translucent in layers about 2 inches thick. The juice from Florida berries was more red than the cooked juice from Maine berries but was opaque in a layer 3 to 4 inches thick.

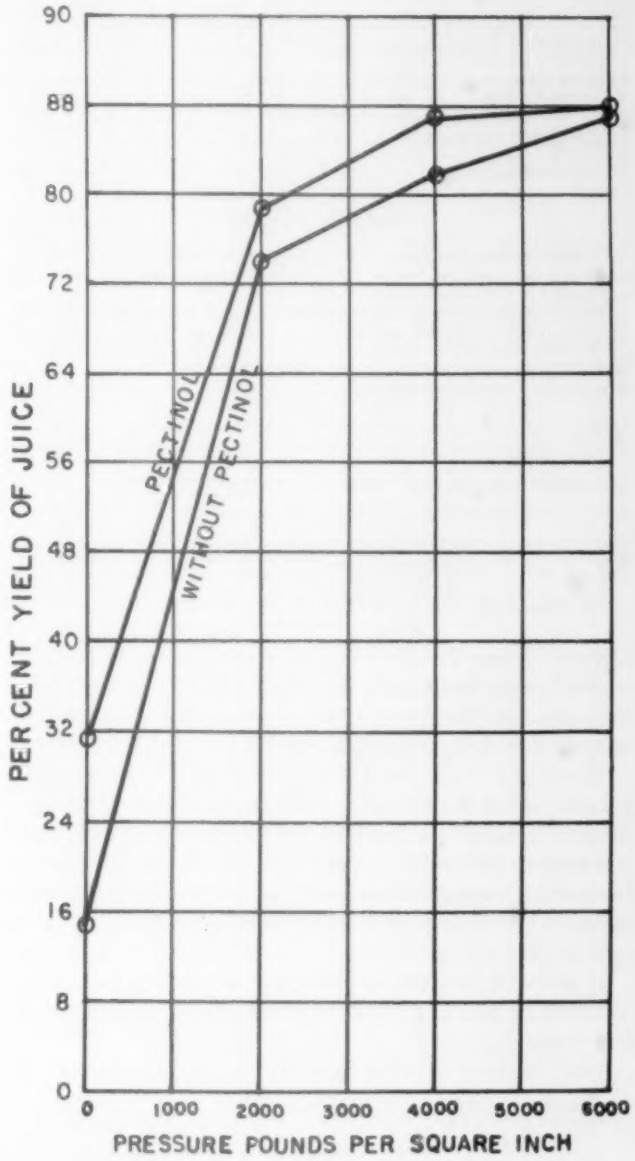

FIG. 1.

Tressler et al. *(6)* stated that most people liked fruit juices with 0.6 to 0.7 percent acid, and blueberries contained only 0.19 percent expressed as citric according to Chatfield and McLaughlin *(1)*. Nelson *(4)* found the acid in blueberries was chiefly citric with some l-malic. Harris and Thomas *(2)* found some tartaric acid and a trace of citric acid in high-bush blueberries *(V. corymbosum)*. Merriam and Fellers *(3)* found .002 percent benzoic and by indirect tests believed there was no quinic acid in high-bush blueberries. A study of the acids in the juice reported here shows there is 0.540 percent total acid and 0.318 percent free acid calculated

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TABLE 1

Analysis of Blueberry Juice

Analysis	Expressed As	Source of Juice				
		Maine *Vaccinium angustifolium*				Florida
		Experimental			Commercial	
		Cooked [b] Drained	Pressed	Pectinol Treated	Cooked [b]	(Probably *V. ashei*) Commercial
Solids	%	10.88		10.76	9.14	10.41
Ash	%	.19			.21	.20
Specific gravity	sp. gr.	1.044	1.043	1.043	1.045	1.040
Viscosity [c]	sec.	23.4	22.3	21.0	26.4	24.0
Reducing Sugar	%	9.95	9.85	9.79	9.93	8.74
Non-reducing Sugar	%	.18	.15		.42	.33
Amino Nitrogen	%	.004	.007	.014	.007	
Total Nitrogen	%	.016			.020	.019
Acidity	pH	3.5	3.6	3.6	3.4	3.3
Acidity titratable [d]	ml.	12.7	13.1	12.2	13.5	12.7
Color [e]	yellow	.214	.309		.059	.169
	red	.333	.171		.311	.677
	blue	.707	.365		1.008	.452

[b] For experimental work, a small amount of water was added to keep the berries from being burned. When the berries had cooked enough to be soft, they were put in a cloth bag to drain. After the free juice had drained, the bag and its contents were pressed. The commercially packed juice from Maine was cooked in a jacketed kettle.

[c] The viscosity record was the time in seconds to drain a 50 ml. pipette at 22.5° C.

[d] Ml. of N/10 NaOH to titrate 50 ml. of blueberry juice to pH 7.0.

[e] Milligrams of Tartrazine No. 94, Amaranth No. 107, and Indigo disulfacid No. 692, respectively, per milliliter required to make a solution with the same color and same intensity as blueberry juice when equal volumes are compared. These dyes could not be satisfactorily mixed to match the juice obtained from berries treated with pectinol.

TABLE 2

Source of Juice	Acid in blueberry juice expressed as percent						
	Total acid calculated as citric	Free acid calculated as citric	Citric	Tartaric	Malic	Malic calculated as citric	Undetermined calculated as citric
Maine	0.540	0.318	0.14	0.00	0.035	0.05	0.35
Florida	....	0.22	0.035	....	....	....	....

.... No analysis.

as citric, Table 2. The juice produced from Maine blueberries contained more free acid and more citric acid than the Florida juice. The Maine juice contained no tartaric acid but some malic acid.

Blueberry juice should be packed with a closing temperature of at least 180° F. When packed in glass containers it would be well to use containers which have a roughened external finish at the bottom and at the top from an eye-appeal standpoint, as sediment occasionally appears and a ring frequently develops at the top surface of the juice.

If properly handled, blueberry juice should have some Vitamin A and C *(3)*. It is an excellent source of iron and manganese *(5)*.

The authors extend grateful acknowledgment to Harry D. Crandon and I. C. Mason for assistance in the analytical work.

LITERATURE CITED

1. Chatfield and McLaughlin. Proximate Composition of Fresh Fruit. U. S. D. A. *Circular No.* 50. (1928).
2. Harris, C. H., and Thomas, W. D. The Fruit of *Vaccinium corymbosum*. *Chem. News* 114, 73 (1916).
3. Merriam, O. A., and Fellers, C. R. Composition and Nutritive Studies on Blueberries. *Food Research* 1, 501 (1936).
4. Nelson, E. K. The Non-volatile Acids of the Pear, Quince, Apple, Loganberry, Blueberry, etc. *Jour. Am. Chem. Soc.* 49, 1300 (1927).
5. Ostermayer, E. Blueberry Wine a Natural Iron-Manganese Preparation. *Pharm. Ztsch.* 47, 316 (1902).
6. Tressler, D. K., Joslyn, M. A., and Marsh, G. L. *Fruit and Vegetable Juices.* The Air Pub. Co., N. Y. (1939).

Dehydrofrozen Peas

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Dehydrofrozen peas (partially dried to reduce weight and volume by about 50 percent) are equal in all respects to frozen peas, both immediately after processing and after one year of storage at —10° F. Processing details are given, and the effects of varying the amount of water removed during the drying operation, and of varying the blanching times and temperatures upon the quality of the product are evaluated.

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The term "dehydrofreezing" designates a process in which fruits and vegetables are partially dehydrated before freezing. This process consists essentially of (a) preparation of fruits, vegetables, or possibly other products in the conventional way; (b) inactivation of enzymes by heat or chemicals, where necessary; (c) a rapid drying cycle to remove part of the water; and (d) freezing and preservation at below-freezing temperatures. An earlier publication on dehydrofreezing by Howard and Campbell *(7)* gives preliminary results

obtained with peas, carrots, cherries, boysenberries, and apricots processed in this manner.

As pointed out in that report, the following advantages are inherent in this method: reduction in volume parallels reduction in weight, resulting in substantial savings in transportation, storage, and packaging costs; much shorter drying cycles are required and more rapid and complete rehydration is possible than for conventionally dehydrated products; quality is comparable to that of conventionally frozen commodities and much superior to that of fully dehydrated products. Recent developments in the field of frozen concentrated orange juice, a related product, illustrate the marketing advantages of such savings in processing and distribution costs.

The experiments described by Howard and Campbell were exploratory in nature. More thorough investigations on the application of this process to certain commodities are under way at this laboratory. This paper reports results obtained with peas.

Materials and Analytical Methods

The peas used were grown in the coastal area of San Mateo County, California, where conditions are favorable for high-quality market peas during several months of the year. The pods were hand-picked at optimum maturity, heavily iced in field crates (0.8 lb. ice per lb. of peas) immediately after picking, and transported to the laboratory within three hours of picking. No provision for quality grading was necessary, as only peas of proper maturity were picked. The following lots of peas in pods were used in the experiments:

Lot 1. 2000 lbs. (Laxton's Progress) picked May 14, 1947. No analytical data available.

Lot 2. 2000 lbs. (Laxton's Progress) picked June 3, 1947. See Table 1 for chemical analyses.

Lot 3. 720 lbs. (Alderman) picked August 18, 1947. Tenderometer reading of unsized peas was 103. Total solids contents of 18.1 and 21.0 were found for the sieve sizes 4 and 6, respectively.

Sugar was assayed by a modification of the method described by Hassid *(5)*; ascorbic acid by the Loeffler-Ponting method *(8)*; crude fiber by the official A. O. A. C. method *(1)*; conversion of chlorophyll to pheophytin by a modification of the method used by Dutton, Bailey, and Kohake *(4)*; and peroxidase by the quantitative method of Masure and Campbell *(9)*. Adequacy of blanch was determined in all cases by testing for peroxidase activity by the semiquantitative method *(9)*. Total solids were determined by a two-stage vacuum drying process, with duplicate one-pound samples in the first drying stage. The peas in each sample were counted so that results could be calculated on a per-pea basis when desired.

Cooking Methods

In the following experiments, dehydrofrozen peas were compared with frozen peas after cooking, to determine the relative organoleptic qualities and rehydration characteristics. The frozen peas were added to one-half their weight of boiling water, and boiled for five minutes from the time the water returned to boiling. Dehydrofrozen peas were added to an amount of cold water equal to that required for complete rehydration to fresh weight plus the amount used in cooking the frozen samples, brought to a boil, and cooked for seven minutes. The cooking procedures for the dehydrofrozen and frozen peas differed only in that the dehydrofrozen were added to cold water and cooked two minutes longer. No preliminary soaking period was required.

Process for Preparation of Dehydrofrozen Peas

The details of the procedure used in preparing dehydrofrozen peas for the experiments reported later are as follows:

Shelling and size grading: The peas were processed in consecutive lots of about 200 pounds of peas in pods so that delays between shelling and blanching would not exceed 30 minutes. They were shelled in a small mechanical podder, size graded and cleaned, and the sieve sizes desired for the experiment retained for processing.

TABLE 1

Chemical Analyses of Raw and Processed Material

Processing Variables		Total Solids (as received)	Total Sugar as Dextrose (as received)		Crude Fiber (MFB)	Enzyme Inactivation		Ascorbic Acid	Chlorophyll Conversion
Blanch Time at 212° F.	Weight Reduction (Raw Weight Basis)					Peroxidase	Catalase		
Sec.	%	%	%	*Mg./pea*	%	%	%	*Mg./pea*	%
0 (Raw Material)	0	18.9	7.12	33.2	7.97	0	0	0.161	2
38	0	19.5	7.20	31.0	8.30	98	99.7	0.139	....
38	40	30.1	....	....	....	98.8	....	0.128	....
38	50	35.0	12.92	31.8	8.40	99.5	....	0.146	5
38	60	45.1	....	....	....	99.0	....	0.132	....
38	70	54.8	....	....	....	99.0	....	0.126	16
55	0	19.4	6.79	27.9	8.77	100.0	100.0	0.132	3.5
55	40	28.8	....	....	....	....	....	0.120	....
55	50	37.0	12.80	29.5	8.34	....	....	0.134	....
55	60	48.4	....	....	....	....	....	0.116	....
55	70	57.8	....	....	....	....	....	0.120	....
80	0	19.2	6.42	25.8	8.57	....	....	0.129	6.5
80	40	30.6	....	....	....	....	....	0.121	....
80	50	34.3	12.19	27.8	8.54	....	....	0.127	....
80	60	46.6	....	....	....	....	....	0.111	....
80	70	59.8	....	....	....	....	....	0.112	....
120	0	19.5	6.32	25.5	8.53	....	....	0.134	8
120	40	29.6	....	....	....	....	....	0.118	....
120	50	33.5	11.73	27.9	9.00	....	....	0.119	....
120	60	46.4	....	....	....	....	....	0.114	....
120	70	61.1	....	....	....	....	....	0.101	....

Blanching: The peas were blanched in a conventional belt-type blancher at temperatures ranging from 212° F. downward to 190° F. Blanching time was varied from that required for adequate enzyme inactivation *(9)* to three times this value. Where temperatures below 212° F. were required, compressed air, filtered and deodorized, was injected into the steam line feeding the blancher. Constant temperatures (± 2° F.) were maintained by an automatic controller which regulated the amount of air injected into the blancher. The peas were weighed, loaded on tared stainless steel trays (1.5 lbs. per square foot), and blanched for the specified times.

Cooling: After blanching, the peas were immediately placed under fog spray nozzles, and the fog-laden air was drawn downward through the peas by a blower system capable of maintaining a free air velocity of 400 feet per minute. A minimum of water, consistent with rapid cooling, was used (0.3 lb. per pound of peas) to reduce leaching losses. This treatment lowered the temperature of the peas to about 70° F. in one minute.

Drying: A cabinet-type dryer with space for four trays (3 feet x 2 feet) was used. Dry and wet bulb temperatures of 160 ± 1° F. and 100 ± 1° F., respectively, and an air velocity of 900 ± 50 feet per minute were maintained during the drying cycle. Peas to be partially dried were removed from the cooler, placed in the dryer, and held until the weight had been reduced by the desired amount. This was determined by removing the loaded trays from the dryer periodically and weighing. The time required to reduce the raw weight by 50 percent was about 30 minutes. Later work has shown that a dry-bulb temperature as high as 200° F. is satisfactory for the drying step; this reduces the drying time mentioned above substantially.

In the terminology used to describe these experiments, extent of desiccation will be expressed as "percent weight reduction," which is based on the raw weight of the shelled peas as determined before blanching. Frozen peas will be regarded as having "zero weight reduction" for simplification in exposition and presentation of graphs, although this is not strictly true because of changes in weight during blanching and tray freezing.

Freezing: The partially dehydrated peas were removed from the dryer and frozen on trays in circulating air at —10° F. Peas to be frozen without dehydration (zero weight reduction) were taken directly from the fog cooler to the freezing room.

Packaging: To prevent thawing, the frozen peas were rapidly packaged in a room maintained at 32° F. They were packed in sanitary-type tinned cans with the equivalent of 120 grams of fresh peas in each container. Since dehydrofrozen peas are reduced in volume during processing, the height of the can was chosen so as to obtain approximately the same head space in each container. For instance, frozen peas (zero weight reduction) were packed 120 grams per four-inch can (211 x 400) while the dehydrofrozen samples with 60 percent weight reduction were packed 48 grams per two-inch can (211 x 200). Samples to be packed in nitrogen were evacuated for 15 seconds in a semi-automatic, vacuum double-seamer (6 to 8 mm. Hg.), the vacuum was released with oil-pumped nitrogen, and the cans were sealed. This reduced the oxygen content of the containers to 2.0 ± 0.5 percent. All samples were held in storage at —10° F. until used.

Comparative Quality of Dehydrofrozen and Frozen Peas

To compare the quality of dehydrofrozen with frozen peas soon after processing and again after 12 months of storage at —10° F., so-called "consumer preference" tests were conducted. Approximately 160 volunteers, including trained as well as untrained tasters from the personnel of this laboratory, participated. Each filled out a questionnaire, prior to the first test, to record previous experience in tasting and knowledge of garden fresh produce. In the statistical analysis of results, the

TABLE 2

Results of "Consumer Acceptance Test" of Freshly Prepared Dehydrofrozen and Frozen Peas

Classification of Group Members		Total Number of Opinions	Total Unable to Identify Duplicates	Number Correctly Identifying Duplicates				Number Correct Decisions for Significance at 5% Level
				Preferred Dehydrofrozen	Preferred Frozen	No Preference	Total Identifying Duplicates	
Trained Pea Tasters:	1st Day	15	9	4	2	0	6	
	2nd Day	17	9	6	2	0	8	
	Total	32	18	10	4	0	14	16
Trained—Other Food:	1st Day	21	14	4	3	0	7	
	2nd Day	20	15	4	1	0	5	
	Total	41	29	8	4	0	12	19
Total Trained:	1st Day	36	23	8	5	0	13	
	2nd Day	37	24	10	3	0	13	
	Total	73	47	18	8	0	26	33
Untrained, but Know Garden-Fresh Produce:	1st Day	53	26	17	10	0	27	
	2nd Day	52	41	8	3	0	11	
	Total	105	67	25	13	0	38	45
Untrained—Do Not Know Garden-fresh Produce:	1st Day	69	46	12	10	1	23	
	2nd Day	66	45	16	3	2	21	
	Total	135	91	28	13	3	44	56
Total Untrained:	1st Day	122	72	29	20	1	50	
	2nd Day	118	86	24	6	2	32	
	Total	240	158	53	26	3	82	97
Grand Total:	1st Day	158	95	37	25	1	63	
	2nd Day	155	110	34	9	2	45	
	Total	313	205	71	34	3	108	121

TABLE 3

Summary of Results of "Consumer Acceptance Test" of Dehydrofrozen and Frozen Peas After Twelve Months of Storage at —10° F.

Classification of Group Members	Total Number of Opinions	Total Unable to Identify Duplicates	Number Correctly Identifying Duplicates				Number Correct Decisions for Significance at 5% Level
			Preferred Dehydrofrozen	Preferred Frozen	No Preference	Total Identifying Duplicates	
Trained Tasters	15	9	4	2	0	6	9
Untrained Tasters	163	110	32	19	2	53	67
Grand Total	178	119	36	21	2	59	73

panel was broken down into sub-groups on this basis, but no selection was used in choosing panel members.

The processed peas used were from Lot 1. Approximately 100 pounds of frozen and 50 pounds of dehydrofrozen peas (50 percent weight reduction, packed in air) were used. The peas had been blanched at 190° F. for 130 seconds [adequate as measured by the method of Masure and Campbell *(9)*].

The peas served to the panel were cooked as described previously but, in addition, were seasoned with butter and salt. They were presented to the panel, with no identifying marks, on two successive days. Each person was given three "unknown" samples. The first day the three consisted of two identical samples prepared from frozen peas and one from dehydrofrozen; on the following day the two identical samples were dehydrofrozen. Each person was given a score sheet containing necessary instructions and asked to check identical samples and indicate his or her preference. Helm and Trolle *(6)* describe this "triangular" method of evaluation. This procedure was repeated after 12 months of storage at —10° F. but modified in that samples were presented to the panel only once.

The results (Tables 2 and 3) show that differences between the samples were so small that analyses of the scores of the panel as a whole, and of each of the subgroups, showed no differences of statistical significance at the 5 percent level.

Effects of Blanching Time on Storage Quality of Dehydrofrozen Peas

Peas from Lot 2 were steam blanched at 212° F. for various times corresponding to an adequate blanch (38 seconds); adequate plus 50 percent (55 seconds); adequate plus 100 percent (80 seconds); and adequate plus 200 percent (120 seconds). Sub-lots from each of the four portions of blanched peas were frozen or dehydrofrozen and packed (in air and in nitrogen) at moisture levels coresponding to weight reductions (based on raw weight) of 0, 40, 50, 60, and 70 percent. Sufficient samples for a comprehensive storage study were packed and the samples were examined immediately after processing, after 6 months, and after 12 months of storage at —10° F.

Results of chemical analyses of processed peas are included in Table 1. The losses of ascorbic acid during blanching ranged from 15 to 20 percent of the total for the times employed. Little additional loss of ascorbic acid occurred during drying where desiccation was not carried beyond that required for weight reductions of 40 and 50 percent.

The conversion of chlorophyll to pheophytin, which commonly occurs during processing of green vegetables, is a good index of color deterioration and is correlated closely with subjective color *(2, 4)*. Conversion of chlorophyll during blanching increased with increasing blanch time, ranging from 2 percent for a 38-second blanch to 8 percent for 120 seconds. During drying the losses of chlorophyll were slight where reductions in weight did not exceed 50 percent of the raw weight.

Crude fiber and sugar data indicated progressive leaching losses with increasing blanch time.

Color, characteristic flavor, objectionable off-flavor, and sweetness were scored by 15 trained judges using a five-point scale. Color was scored subjectively on whole cooked peas under special tungsten filament lamps and filters (7400 K.). Sweetness, characteristic flavor, and objectionable off-flavor were scored on a warm puree prepared by blending the cooked peas with the residual cooking liquor, plus the amount of water lost during cooking, until a smooth mixture was obtained. Use of pureed peas for taste tests reduces lack of uniformity between peas in the same sample to a minimum.

Organoleptic data from the assay immediately after processing showed that neither the blanching times nor the weight reductions employed had much effect on the flavor or sweetness of the dehydrofrozen peas. No color data are available for this test period.

After six and twelve months of storage at —10° F. the taste panel could not distinguish between corresponding samples packed in nitrogen and in air by the "triangular" test described earlier. Therefore only data obtained from air-packed samples are reported. Characteristic flavor, objectionable off-flavor, and sweetness were not seriously affected by the blanching time or the extent of drying when the samples were assayed for organoleptic quality at the two storage intervals. There was some indication that the samples with lowest moisture content (70 percent weight reduction) had developed slightly more objectionable off-flavor than the other samples.

Subjective color scores at the two storage intervals are shown in Figure 1. Blanching time has little effect on the color of the dehydrofrozen samples; little deterioration of color was observed if the weight reduction

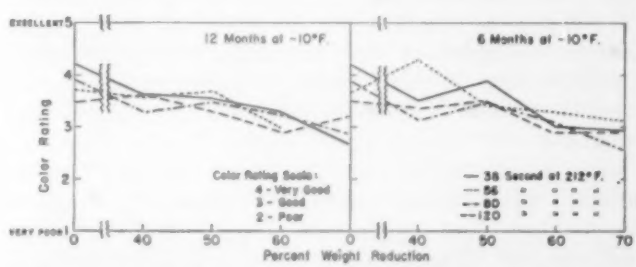

FIG. 1. Effect of Blanching Time and Weight Reduction on Color of Dehydrofrozen Peas After Six and Twelve Months of Storage at —10° F.

did not exceed 50 percent of the raw weight. Desiccation beyond this point resulted in progressive color deterioration. Undesirable color changes, where encountered, can possibly be controlled by certain preblanching treatments *(2)*.

Samples dried beyond 50 percent weight reduction did not rehydrate as completely as other samples, when cooked by the rapid method described in an earlier section.

Drained Weights and Volumes of Dehydrofrozen and Frozen Peas

The drained weights and volumes of cooked dehydrofrozen peas, as compared with frozen peas, are important factors in the economics of dehydrofreezing. These are presumably measures of the extent of rehydration. High drained weights and volumes are especially desirable for institutional uses where the drained volume will determine the number of servings obtainable from a given weight of peas. Though all available data indicate that cooked dehydrofrozen and frozen peas have the same nutritive value *(3)* on the fresh-weight basis, it is obvious that drained volume of dehydrofrozen peas should not be less than that of frozen if the two are to compete on an equal price basis. An experiment was conducted to determine the effect of blanching time and temperature on the drained weights and volumes of dehydrofrozen and frozen peas after cooking.

Shelled peas from lot 3 were size graded and the sieve sizes 4 and 6 were retained and processed separately. Two trays of peas af each sieve size were processed for each of the 16 blanching conditions used in the experiment. These conditions consisted of four blanching treatments, namely adequate, adequate plus 50 percent, adequate plus 100 percent, and adequate plus 200 percent, obtained at each of four temperatures, 190, 197, 204, and 212° F. One tray of peas from each of the 32 pairs of duplicate samples (4 temperatures x 4 times x 2 sieve sizes) was divided into two equal parts, sealed in No. 1 tinned cans and frozen at —10° F., giving 32 paired frozen samples. The peas on the remaining 32 trays were given a similar treatment, but partial dehydration (50 percent weight reduction) was interposed between blanching and freezing.

The 32 pairs of dehydrofrozen samples were cooked and their drained weights and volumes determined by directly weighing and measuring volumes after draining on a Büchner funnel with vacuum for one minute. One of each of the paired frozen samples was handled in the same way; the other sample was used in an investigation of splitting of pea skins, to be described in the next section. Weights of dehydrofrozen and frozen peas corresponding to 120 grams of *fresh* material were used in all cases for determining drained weights and volumes.

The results for frozen peas were not significantly affected by blanching conditions (Figure 2). Higher temperatures and longer times favored higher drained weights and volumes for the dehydrofrozen samples; with the larger peas (sieve size 6), where blanching was adequate plus 100 percent, or more, and carried out at

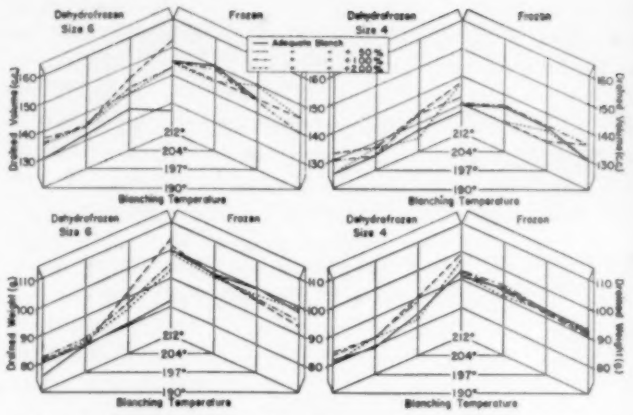

FIG. 2. Effect of Blanching Time and Temperature (°F.) on Drained Weights and Volumes of Cooked Dehydrofrozen and Frozen Peas (120 g. fresh-weight basis).

212° F., drained weights and volumes were comparable to those obtained with the frozen samples; somewhat milder conditions resulted in satisfactory drained weights and volumes for the smaller peas.

Splitting of Skins

The splitting of pea skins was investigated on one of each of the 32 paired samples of frozen peas described in the previous section. The samples were thawed in running water and the number of "loose" skins and the number of peas with "ruptured" skins were determined by actual count. According to the terminology used in this experiment, peas with "loose" skins had skins and cotyledons separated as defined by the United States Department of Agriculture *(10)*. "Ruptured" skins were not intact, but the skins and cotyledons had not separated. The results are shown in Figure 3. Temperatures of 190 and 197° F. resulted in only 15 to 25 percent "ruptured" skins. At the higher temperatures and the longer blanching times, the number of peas with "ruptured" skins mounted rapidly. It should be pointed out that "ruptured" skins are not classified as defects according to the standards for frozen peas. The percentages of peas with "loose" skins were less than one percent in all instances and were consistently lower for the larger sizes.

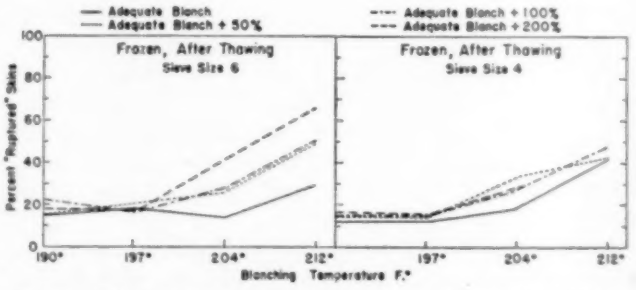

FIG. 3. Effect of Processing on the "Rupturing" of Pea Skins.

The percentage of "ruptured" skins could not be determined on dehydrofrozen peas because of the wrinkled appearance of the product. However, other experiments in this laboratory have shown that practically all damage to pea skins occurs during shelling and blanching, with very little resulting from subsequent drying or freezing

operations; hence the results obtained with frozen peas can be used as a measure of overall damage to be expected during the production of the dehydrofrozen product. Therefore blanching conditions resulting in high drained weights and volumes for cooked samples of dehydrofrozen peas would be expected to cause a high percentage of "rupturing" (Figures 2 and 3). If considered desirable, other methods of rehydration prior to cooking, designed to increase the drained weights and volumes of samples processed under conditions minimizing "rupturing," could doubtless be developed, although probably with some loss of speed and convenience at the rehydration step.

Conclusions

1. Initially and after six and twelve months' storage at —10° F., there is little difference between cooked dehydrofrozen and frozen peas where weight reductions of 50 percent of the raw weight are employed. Further dehydration, up to 60 percent of raw weight, results in some loss of desirable color, but does not affect other organoleptic qualities. Weight reductions as high as 70 percent do not seem desirable in the light of present results.

2. Cooking methods for dehydrofrozen and frozen peas are quite similar, because the dehydrofrozen product does not require any preliminary soaking prior to cooking.

3. The blanching procedure employed in processing peas for dehydrofreezing seems to be more critical than that used in conventional freezing processes. Time and temperature of blanching have little effect on the drained weights and volumes of cooked frozen peas under the conditions of these experiments. However, in processing peas for dehydrofreezing so as to obtain high drained weights and volumes by using quick, easy cooking methods, less latitude in blanching procedure seems to be permissible.

4. Long blanching times and high blanching temperatures, which favor high drained weights and volumes in cooked dehydrofrozen peas, result in a high percentage of "ruptured" skins.

LITERATURE CITED

1. Association of Official Agricultural Chemists, Official and Tentative Methods of Analysis, 6th Ed., 932 p. (1945).
2. Blair, J. S., and Ayres, T. B. Protection of natural green pigment in canning of peas. *Ind. Eng. Chem.*, **35**, 85 (1943).
3. Boggs, M. M. Unpublished data from Western Regional Research Laboratory.
4. Dutton, H. J., Bailey, G. F., and Kohake, Eleanor. Dehydrated spinach. Changes in color and pigments during processing and storage. *Ind. Eng. Chem.*, **35**, 1173 (1943).
5. Hassid, W. Z. Ferricyanide and ceric sulfate titration. *Ind. Eng. Chem., Anal. Ed.*, **9**, 228 (1937).
6. Helm, E., and Trolle, B. Selection of a taste panel. Wallerstein Laboratories *Communications*, **9**, No. 28, 181 (1946).
7. Howard, L. B., and Campbell, H. Dehydrofreezing—New way of preserving food. *Food Ind.*, **18**, 674 (1946).
8. Loeffler, H. J., and Ponting, J. D. Ascorbic acid. Rapid determination in fresh, frozen, or dehydrated fruits and vegetables. *Ind. Eng. Chem., Anal. Ed.*, **14**, 846 (1942).
9. Masure, M. P., and Campbell, H. Rapid estimation of peroxidase in vegetable extracts—an index of blanching adequacy for frozen vegetables. *Fruit Prod. Jour.*, **23** (12) :369 (1944).
10. U. S. Department of Agriculture, War Food Administration, Tentative United States Standard for Grades of Frozen Peas. (March 15, 1945).

Sorbic Acid as Inhibitor of Scum Yeast in Cucumber Fermentations

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Lactic acid fermentation occurs in the presence of sorbic acid which totally inhibits yeasts and molds. In the presence of a concentration of 0.1 percent, acid development is slow, but eventually reaches a level in salt brines higher than the highest attained in the controls. Cucumbers fermented in the presence of sorbic acid remain firm and crisp and are cured normally, with no effect upon the flavor of the finished pickle.

In 1945 Gooding *(9)* disclosed in a patent the effectiveness of a group of organic acids and esters, having an unsaturation at the alpha position, in the inhibition of yeasts, molds and other spoilage agents. Of these, a hexadienoic acid, sorbic,[c] was selected as being useful and desirable in foods because of its lack of odor and flavor, and its non-toxicity to humans. The latter point was confirmed recently by Smyth and Carpenter *(15)*.

Since scum yeasts and molds possess primarily an oxidative mechanism[d] for obtaining energy, it seemed probable that where they are involved in spoilage, sorbic acid could be employed as an inhibitor, yet permit the normal fermentation of cucumbers in the preparation of salt stock through the activities of the lactic acid producing bacteria. Preliminary studies showed that at concentrations of sorbic acid as low as 0.005 percent various

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[b] In cooperation with the Department of Horticulture, University of Tennessee.

[c] Obtainable from Carbide and Carbon Chemicals Corporation.

[d] The physiological activity of sorbic acid upon microorganisms is now being investigated.

oxidative yeasts, recently shown by Etchells and Bell *(4)* to be associated with pickle scum, were inhibited, while acid production by *Leuconostoc* and *Lactobacillus* freshly isolated from fermenting cabbage was unimpaired at all concentrations of sorbic acid up to 0.1 percent. At this level acid production by *Leuconostoc* was delayed.

The detrimental effect of scum yeasts is shown by the fact they oxidize the organic acids produced in the normal fermentation [Brown *(2)*, Riley *(14)*], and thus lower the preserving value of the brine. Joslyn *(11)* reported a drop in titratable acidity from 1.13 to 0.25 percent in 26 days. Fabian and Johnson *(7)* reported that *Bacillus mesentericus fuscus* growing in 11 percent (40 degree salometer) brine in acidities up to 0.2 percent acetic or 0.3 percent lactic acids produces a pectinolytic enzyme, protopectinase, which is active at 0.2 percent acidity in causing slippery, soft and mushy pickles.

Fabian, Bryan and Etchells *(6)* demonstrated that placing fermentation tanks under cover results in much heavier scum formation with lower titratable acidity of the brine. Rahn *(13)* proposed daily irradiation with ultra violet light for 30 minutes, following the observation that sunlight was the active factor in reducing scum on tanks exposed to the atmosphere. The effectiveness of the treatment was confirmed by Fabian and Bryan *(5)*, but it is rendered impracticable by the cost.

No acceptable method for the control of scum has been adopted. Mineral oil at a thickness of 6 mm. has been suggested. Initially high concentrations of salt are not effective and as shown by Jones *(10)* depress the rate of formation and final concentration of acid. Erickson and Fabian *(3)* and Fellers and Levine *(8)* demonstrated the effectiveness of acetic acid in inhibiting yeasts, but Fabian (personal communication) states that its use is detrimental to the development of the cured pickle. Blum and Fabian *(1)* advocated the use of mustard oil emulsions, but these have limited application because of volatility.

Experimental Procedure and Results

Although sorbic acid and its sodium salt appear to be equally effective in laboratory tests with pure cultures and artificial media, cucumber fermentations were carried out with the acid only. Fresh cucumbers varying in length from two to seven inches were washed briefly in cool tap water and covered with 40 degree (salometer) brine to which sorbic acid was added. The crocks, ranging in size from two to ten gallons, were covered with paper and held at a temperature varying from 85° F. (29.4° C.) to 92° F. (33.3° C.). At first daily, and later occasional, titrations were made and pH readings were taken. The salt content of the brine was maintained at the 40 degree level, compensation being made for temperature in the adjustment.

Most lots were salt stock fermentations, but one lot of dill fermentations, beginning with 29 degree brine, was made. In both types of fermentations sorbic acid was added in concentrations ranging from 0.005 to 0.1 percent. Typical results are shown in Figures 1, 2 and 3. In Figures 1 and 2, curves for concentrations of

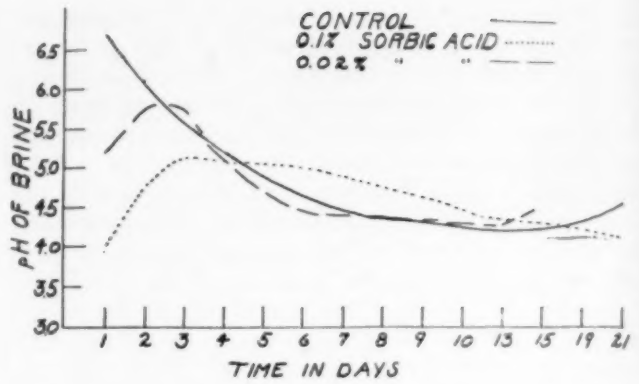

FIG. 1. The effect of sorbic acid in several concentrations on the pH in normal cucumber fermentation.

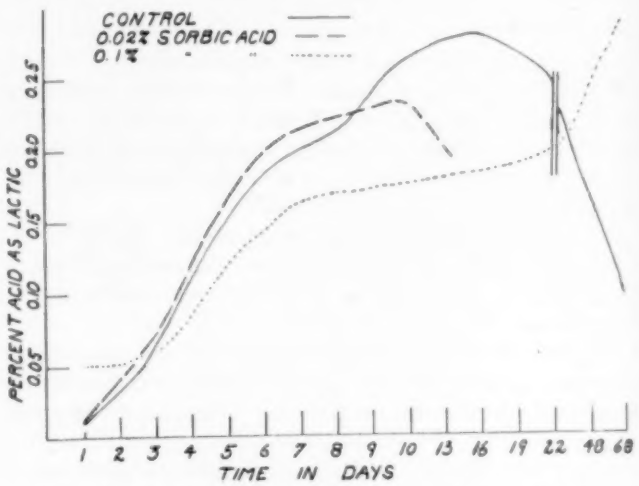

FIG. 2. The effect of sorbic acid in several concentrations on the percent acid calculated as lactic during normal cucumber fermentation.

sorbic acid of less than 0.02 percent are omitted since they approximate those for the controls.

Sorbic acid is strongly ionized with the result, as shown in Figure 1, that the initial pH is low. This rises as some of the acid is absorbed by the cucumbers, and again drops as the lactic acid fermentation is initiated by the bacteria. The pH and also the titratable acidity of salt stock in the controls and those receiving lesser quantities of sorbic acid fluctuated as surface growth developed and was skimmed off.

It became apparent that concentrations of less than 0.1 percent sorbic acid were ineffective in stopping development of surface growth, although extensive inhibition compatible with the concentration was noted. Salvaged cucumbers taken from such crocks and placed into acidified brine with 0.1 percent sorbic acid developed no surface scum.

At the highest concentration of sorbic acid, the percent of lactic acid development was slow as compared with the control, but it continued to rise slowly and steadily to the 68th day, when further titrations were discontinued.

The rates of curing of cucumbers as determined by the alteration of the interior of the cucumber from the typically white, fresh appearance to the somewhat glassy, greenish color of the cured cucumber were alike in both

sorbic acid treated and control crocks. The cucumbers in the treated crocks retained their hard, firm qualities throughout, with no softening or slipperiness, while those in control crocks and those receiving minimal quantities of sorbic acid became slippery, soft and finally mushy, at which time they were discarded as unfit for use.

The final percent of acid titrated as lactic may appear to be low, but is in line with the results published by Jones *(10)*, by which it is shown that increasing concentrations of salt have a depressant effect upon formation of lactic acid.

Figure 3 illustrates the appearance of two crocks of fermenting salt stock at ten days, one without and one with 0.1 percent sorbic acid. The control crock was eventually discarded, but the treated crock remains as

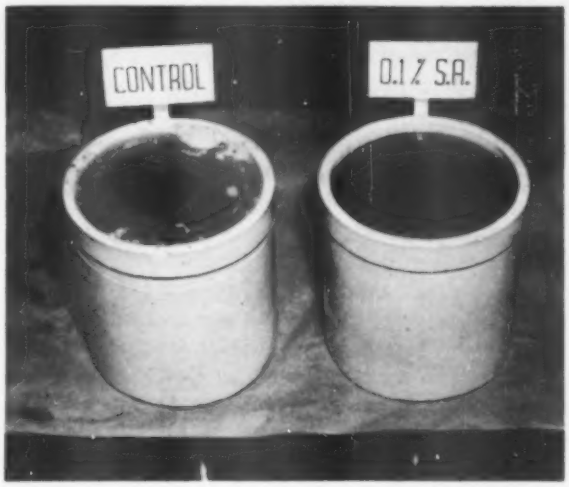

FIG. 3. Control and sorbic acid treated salt stock fermentation of cucumbers at 10 days. The crock at the right, protected with paper, has remained clear for five months of storage, while cucumbers in the control crock have decayed.

clear after five months of storage, with no added salt, as at the time the photograph was taken.

To ascertain the possible effect of sorbic acid upon the flavor of cucumbers fermented in its presence, salt stock was freshened according to the method of Krum and Fabian *(12)*, and made into dills with vinegar, salt and dill oil. Numerous tasters declared them good, no adverse flavor being detected. Similarly, cucumbers in the dill fermentation were good, but salty.

Discussion

Where the work of Gooding *(9)* has shown that sorbic acid and similar compounds with an alpha unsaturation inhibit yeasts and molds, our work demonstrates that an acid fermentation will occur in the presence of sorbic acid.

Numerous trials have demonstrated that concentration of 0.1 percent sorbic acid inhibits yeasts and molds completely, under conditions otherwise extremely conductive to growth of these organisms. Under these conditions, however, production of lactic acid by the acid producing bacteria continues steadily, being slightly inhibited during the early period of fermentation, but eventually proceeding to give a concentration of acid higher than the highest attained in the controls. Partial but not complete inhibition of surface growths is obtained at concentrations of 0.02 percent and less. The inhibition at lesser concentrations is insufficiently effective to be useful.

Smyth and Carpenter *(15)* determined the LD50 dose for rats to be 7.36 g./kg., and the maximum daily dose over a 30 day feeding period not causing depressing or micropathological symptoms to be 0.11 g./kg. for the acid, and 1.08 g./kg. for the sodium salt. Even assuming a substantial portion of the acid to be taken up by the cucumber, it would appear extremely unlikely that quantities sufficient to be toxic would be ingested on consumption of the finished pickle; however, further toxicological studies are indicated before the proposed use of sorbic acid is undertaken commercially.

In this work only the acid was employed, but it appears (Gooding, personal communication) that the sodium salt may be as effective when the pH is maintained below 6. Such a value would be quickly attained in cucumber fermentations. Sorbic acid also raises the possibility of employing brines of lesser salt concentrations to enable a higher final acidity. These possibilities, partially indicated by laboratory trials, will be investigated during the coming season.

LITERATURE CITED

1. BLUM, H. B., AND FABIAN, F. W. Spice oils and their components for controlling microbial surface growth. *Fruit Prod. J. and Amer. Vinegar Ind.*, **22**, 326 (1943).
2. BROWN, C. W. Notes on brine pickle fermentation. *J. Bact.*, **1**, 104 (1916).
3. ERICKSON, F. J., AND FABIAN, F. W. Preserving and germicidal action of various sugars and organic acids on yeasts and bacteria. *Food Res.*, **7**, 68 (1942).
4. ETCHELLS, J. L., AND BELL, T. A. Film yeasts on commercial cucumber brines (abstract). *Food Tech.*, **4** (1950).
5. FABIAN, F. W., AND BRYAN, C. S. An attempt to prevent the formation of Mycoderma scums on pickle brine by use of a vapor mercury lamp. *Fruit Prod. J. and Amer. Vinegar Ind.*, **11**, 134 (1932).
6. FABIAN, F. W., BRYAN, C. S., AND ETCHELLS, J. L. Experimental work on cucumber fermentation. *Mich. Agr. Exp. Sta. Tech. Bull.*, **126** (1932).
7. FABIAN, F. W., AND JOHNSON, E. A. Experimental work on cucumber fermentation. *Mich. Agr. Exp. Sta. Tech. Bull.*, **157** (1938).
8. FELLERS, C. R., AND LEVINE, A. S. The toxicity of certain organic acids to yeast and mold in the presence of fruit juice-syrup mixtures. *J. Milk and Food Tech.*, **12**, 351 (1949).
9. GOODING, C. M. Process of inhibiting growth of molds. U. S. Patent, 2,379,294 (1945).
10. JONES, I. D. Influence of brine salinity on acid formation during salting of cucumbers. *Ind. Eng. Chem.*, **32**, 858 (1940).
11. JOSLYN, M. A. Some observations on softening of dill pickles. *Fruit Products J.*, **8**, 19 (1929).
12. KRUM, J. K., AND FABIAN, F. W. The bacteriology of the freshening process in pickle manufacture. *Fruit Prod. J. and Amer. Food Manuf.*, **28** (9), 260 (1949).
13. RAHN, O. Prevention of scum on brine pickles. *The Canner and Dried Fruit Packer*, **37** (20), 44 (1931).
14. RILEY, H. N. Preliminary notes on the curing of cucumber pickles. *Science*, **39**, 954 (1914).
15. SMYTH, A. F., AND CARPENTER, C. P. Further experience with the range-finding test in the industrial toxicology laboratory. *J. Ind. Hyg. Toxicol.*, **30**, 63 (1948).

Dehydroacetic Acid A New Microbiological Inhibitor[a]

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The antimicrobial, chemical, and physical properties of dehydroacetic acid are described. Results are given on laboratory tests with treated wraps using cheese, butter and bread. Laboratory experiments using dehydroacetic acid in a dried fruit dip indicate that this compound prevents mold on dried fruit that has been hydrated.

Losses arising from microbial destruction became acute as a result of global shipments of supplies to our armed forces during World War II. The present and continuing shortage in world food supplies adds to the need for decreasing food waste as well as increasing food production. While the importance of quality products and cleanliness in plant processing practice are basic, the loss resulting from unavoidable microbial deterioration creates a legitimate place for the use of suitable microbiological inhibitors in the food industry.

Inorganic salts, benzoic acid and its esters, p-hydroxybenzoates, salicylates, sugar and simple aliphatic acids have been cited by Jacobs *(3)* as examples of compounds that have been used to inhibit microbial activity in foodstuffs. Recently certain vanillic acid esters *(4)* have shown antimicrobial activity when added to foods or used in a wrapper for food.

Sulfur dioxide *(9)* ethoxyethane and propoxypropane *(10)* have been studied and recommended for use in limiting microbial destruction in packaged food because of their combined fumigant and antimicrobial activity.

Thiourea, thioacetamide, 2-aminothiazole and 8-hydroxyquinoline *(1)* are among the compounds which have been reported as being effective in coatings in the control of stem-end rots and blue-green mold on citrus fruit.

Many of the compounds cited have certain limitations. Some are toxic, some are relatively ineffective against microorganisms, while others are limited in use because of their taste, odor or lack of water solubility. There is a legitimate need for compounds that can be used to keep quality products in a good condition, provided no health hazards result through their use.

Recent studies on the relationships between chemical structure and antimicrobial activity *(5)* point to a correlation in many cases between an alpha, beta unsaturated ketone structure and bacterial inhibition. For example, clavacin, fumigatin, penicillic acid and kojic acid are among antibiotic products that contain the alpha, beta unsaturated ketone configuration. The possibility of the relationship of this structure to bacterial inhibition led to a study of simple compounds containing this structure.

The study of a group of 1, 2- and 1, 4-pyrones *(11)* has shown that dehydroacetic acid [3 acetyl-6-methyl-1, 2H-pyran-2, 4 (3H) dione] has properties which fit it for use as a microbiological stabilizer, possibly in the food field. Extensive toxicological work including two year feeding tests with rats *(8)* and pharmacological studies *(6, 7, 12)* have been carried out so that the health problems associated with the use of this compound can be properly evaluated.

Methods

Preliminary screening tests for microbiological stabilizers were developed using test organisms which are of economic importance in causing the spoilage of foods. A saturated solution of each experimental compound was prepared using a suitable hot, agar medium as the solvent. Plates were poured and after the agar had solidified an additional amount of the compound was placed in a line along the middle of the Petri plate. The medium was then streaked at right angles to the line of the compound using a 24-hour broth culture of the organism or a culture from a spore suspension. After incubation at an optimum temperature for growth of the test organisms, the plates were read. A two-day period of incubation was used for bacteria and yeasts and a period of 7 to 14 days was necessary before final observation on fungi. Table 1 contains the organisms used in screening and their relation to food spoilage.

Compounds exhibiting activity by the preliminary screening tests were evaluated further by studying their effectiveness under conditions simulating usage as closely as possible.

TABLE 1

Organisms Used in Screening Studies

Organism	Effect Produced
Sclerotium rolfsii	Blight on potatoes
Phomopsis citri	Stem-end rot, citrus fruit
Bacillus mesentericus	Ropiness in bread
Aerobacter aerogenes	Common food contaminant, ropy fermentation
Erwinia caratovora	Bacterial soft rot in potatoes
Penicillium digitatum	Blue-green mold on citrus fruit
Saccharomyces cerevisiae	Extended fermentation causes off taste in beers
Lactobacillus plantarum	Off tastes in wine
Rhizopus nigricans	Bread mold, common food contaminant
Aspergillus niger	Black discoloration of foodstuffs

These screening and evaluation studies showed that one compound, dehydroacetic acid (hereafter referred to as DHA[b]), has properties that suggest its use as a microbiological stabilizer in the food field and as a preservative for cosmetics.

Table 2 contains the results of antimicrobial laboratory tests obtained with DHA.

The antimicrobial activity of DHA and its sodium salt (DHA-S) was compared at different pH's. The results of Table 3 indicate that there is some decrease in activity with an increase in pH. However, this change in activity is not as great as that exhibited by the carbo-

[a] Presented at a meeting of Great Lakes Section, IFT, Battle Creek, Michigan, November 4, 1949.

[b] DHA and DHA-S are trade names of The Dow Chemical Company for dehydroacetic acid and its sodium salt respectively.

TABLE 2

Antimicrobial Activity of Dehydroacetic Acid[a]

Test Organism	Concentration (%) Permitting Growth	Concentration (%) That Inhibits Growth
Aerobacter aerogenes	0.2	0.3
Alkaligenes faecalis	0.3	0.4
Aspergillus niger	0.03	0.05
Bacillus cereus	0.2	0.3
Bacillus megatherium	0.2	0.3
Bacillus mesentericus	0.2	0.3
Bacillus subtilis	0.2	0.3
Escherichia coli	0.3	0.4
Lactobacillus plantarum	0.08	0.10
Penicillium digitatum	0.02	0.03
Penicillium expansum	0.008	0.01
Pseudomonas aeruginosa	0.3	0.4
Rhizopus nigricans	0.04	0.05
Saccharomyces cerevisiae	0.05	0.1
Salmonella pullorum	0.2	0.3
Salmonella typhosa	0.1	0.2
Staphylococcus aureus	0.2	0.3
Streptococcus pyogenes	0.2	0.3
Trichophyton mentagrophytes	0.004	0.005
Trichophyton interdigitale	0.001	0.005

[a] Test period—7 days for bacteria and yeast, two weeks for fungi.

xylic acids that were listed. They are much less active in an alkaline pH range than in an acid range.

Physical and Chemical Properties of DHA

Dehydroacetic acid is a white, odorless compound. At concentrations suitable for use it is odorless, colorless and tasteless. The solubilities of DHA and its sodium salt in several solvents are included in Table 4.

Studies on the stability of DHA towards heat have been made. Duplicate samples of autoclaved (15 lbs. pressure for one hour 120-130° C.) and unautoclaved solutions were compared using the test organisms *Aspergillus niger* and *Rhizopus nigricans*. The results shown in Table 5 were obtained in agar plate tests:

These data indicate that autoclaving has caused a slight decrease in activity against the two organisms tested. However, the loss in dehydroacetic acid whether by volatilization or chemical decomposition is not great when one considers the rigorous conditions to which the compound was subjected.

Laboratory Tests on Possible Applications of DHA as a Microbiological Stabilizer

The following results are illustrative of laboratory experiments:

1. DHA In Antimycotic Wraps.

(a) *Cheese.* Antimycotic cheese wraps[c] have been prepared in which DHA has been added to the wax coating used with the paper.[c] Samples of cheese were wrapped and stored at room temperature for varying

[c] These wraps were prepared through the courtesy of the Marathon Corp., Menasha, Wisconsin.

TABLE 4

Solubility Data: Dehydroacetic Acid (DHA) and Its Sodium Salt (DHA-S)

	DHA	DHA-S
Acetone	22[a]	0.2
Benzene	18	<0.1
Carbon Tetrachloride	3	<0.1
95% Ethanol	3	1
Ether	5	<0.1
Glycerine	<0.1	15
n-Heptane	0.7	<0.1
Methanol	5	14
Olive Oil	1.6	<0.1
Propylene Glycol	1.7	48
Water	<0.1	33

[a] Solubility (Approx.), Grams per 100 Grams Solvent, at 25° C.

TABLE 5

Effect of Heat on Fungistatic Activity of Dehydroacetic Acid

Organism	Percent Concentration DHA	Mildew Readings	
		Autoclaved Sample	Sample Not Autoclaved
A. niger	0.05	Medium	Light
	0.06	Light	None
	0.07	None	
R. nigricans	0.015	Heavy	Light
	0.020	Light	None
	0.025	None	

periods of time depending upon the speed with which mold developed on the untreated control samples. Usually considerable mold formed within one to two weeks. Figure 1 illustrates the beneficial effect of 2% DHA in the wax coating. Experiments are now under way at the Marathon Corporation of Menasha, Wisconsin, to determine the method of applying DHA to a wrap to obtain optimum antimicrobial activity.

Work in our laboratory indicates that wraps treated

Fig. 1. Cheese Wraps. Exposure: 2 Weeks at 25° C.

with DHA will also protect cream cheese from mold and, in addition, decomposition by bacteria and yeasts is retarded.

(b) *Butter.* DHA has been tested as a mildew retarder for butter. Unsalted creamery butter was inoculated with mold spores of *Penicillium expansum*. Subse-

TABLE 3

Antimicrobial Activity of Dehydroacetic Acid, Benzoic Acid, Propionic Acid and Their Sodium Salts

Organism	Saccharomyces cerevisiae	Aerobacter aerogenes	Lactobacillus plantarum	Staphylococcus aureus		
Compound				pH-5.0	pH-7.0	pH-9.0
Dehydroacetic Acid	0.01-0.025[d]	0.20-0.30[d]	0.075-0.10[d]	0.2-0.3[d]	0.2-0.3[d]	0.2-0.3[d]
Sodium Salt of Dehydroacetic Acid	0.025-0.05	0.50-0.60	0.10-0.20			
Propionic Acid	0.75-0.10	0.10-0.25	1.0-2.0			
Sodium Propionate	>7.5	>5.0	>7.5			
Benzoic Acid	0.25-0.50	0.10-0.25	0.25-0.50			
Sodium Benzoate	0.50-0.75	1.0-2.5	1.0-2.5			

[d] First value: Concentration allowing growth (%). Second value: Concentration preventing growth (%).

quent storage tests indicated that the treated wraps inhibited mold growth in contrast with the untreated controls.

(c) *Bread.* Individual slices of bread (Figure 2) as well as whole loaves of sliced bread (Figure 3) were wrapped in wraps treated with DHA. Mold was inbihited completed for at least one week when stored at 30° C. in a tropical chamber. However, protection was afforded only where there was contact between the wrap and the bread. The inside of the loaf of bread of Figure 3 had some mold.

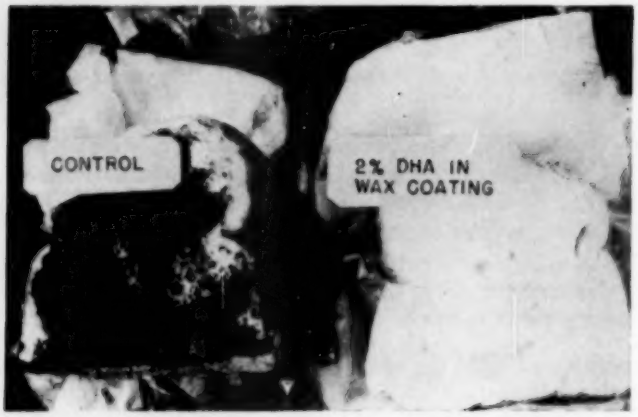

FIG. 2. Bread Wraps. Exposure: 7 Days at 30° C.

FIG. 3. Bread Wraps. Exposure: 1 Week at 30° C.

2. DHA IN DRIED FRUIT DIPS.

(a) *Prunes.* At the present time prunes are dehydrated to a moisture content of 18-22% and marketed as the dried fruit. Although these prunes do not mold readily, they are unattractive, unappetizing, and need to be hydrated before eating. On the other hand prunes containing 30% or more moisture are tasty and appetizing. However, there is one drawback; for, with an increase in moisture content, the prunes become increasingly susceptible to mold.

An investigation was carried out to determine the effectiveness of DHA-S in inhibiting the growth of mold on prunes. Dried prunes were hydrated by placing the fruit in boiling water for various lengths of time. The hydrated prunes were dipped in solutions containing varying concentrations of the soluble form of DHA and immediately spread on paper toweling to drain. The treated samples and controls were then tested by two procedures: exposure in open dishes in a tropical chamber (Figure 4) and similar exposure of fruit packaged in Saran bags sealed with scotch tape (Figure 5). Analytical data were obtained on the DHA content

FIG. 4. Hydrated Prunes Dipped in DHA-S Solutions. Exposure: 3 Weeks in Tropical Chamber.

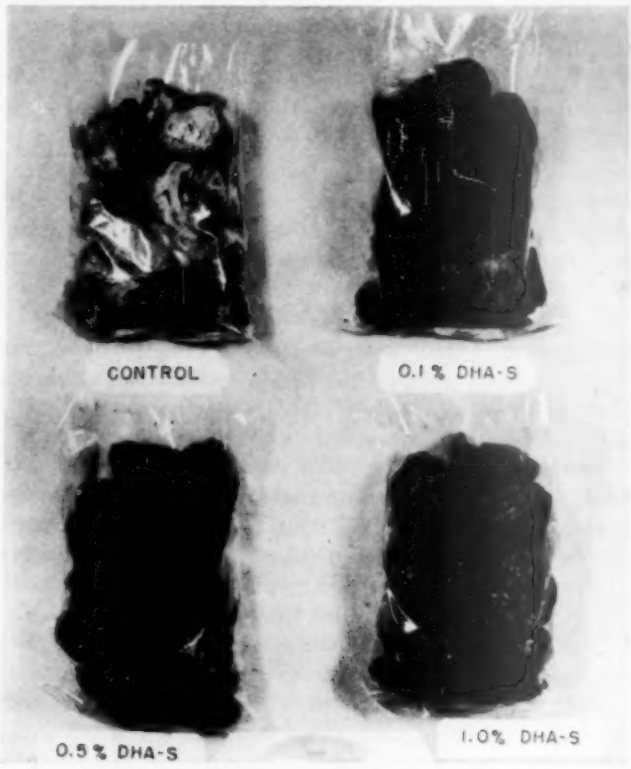

FIG. 5. Hydrated Prunes Dipped in DHA-S Solutions. Exposure: 7 Weeks in Tropical Chamber.

of prunes before and after storage. The results of these analyses *(2)* are included in Table 6.

These results indicate that DHA is slowly lost during exposure of treated prunes and that the loss is less in the bagged fruit.

Further work not illustrated here shows that there is a relationship between the water content of prunes and their susceptibility to mildew. As the moisture content of the prunes increases, more DHA is required for mold inhibition.

Laboratory studies indicate that dried peaches and dried apricots can be treated in the same way as prunes

TABLE 6

The Dehydroacetic Acid Content of Dipped Prunes

Concentration of DHA-S in Dip (Percent)	Concentration of DHA (%) on Treated Prunes		
	Initially	After 3 Weeks at 30° C.	
		Open Dish	Saran Bag
0.1	0.0017	0.0005	0.0007
0.2	0.0023	0.0005	0.0009
0.3	0.0025	0.0008	0.0014
0.4	0.0030	0.0009	0.0020

and that mold growth can be controlled with the use of DHA.

Summary

The antimicrobial, physical and chemical properties of dehydroacetic acid are such that this compound offers possibilities as a microbiological inhibitor.

Laboratory tests indicate that dehydroacetic acid and its sodium salt are effective in inhibiting undesirable microbial activity when used in food wraps or as a dip for dried fruits such as prunes, peaches and apricots.

Some applications in which dehydroacetic acid would be added to food either directly or indirectly during food processing may become feasible, provided it is possible to establish to the satisfaction of governmental food control agencies that, (1) such use of the inhibitor is justified, and (2) that the inhibitor when thus used has no harmful physiological effect on consumers.

BIBLIOGRAPHY

1. Childs, J. F. L., and Siegler, E. A. "Controlling Orange Decay." *Ind. Eng. Chem.* **38**, (1), 82 (1946).
2. Daniels, O., and Stenger, V. A. "The Determination of Dehydroacetic Acid and its Sodium Salt." The Dow Chemical Company. Unpublished data.
3. Jacobs, M. B., 1944. "The Chemistry and Technology of Food and Food Products." Interscience Publishers, Inc., New York, N. Y.
4. Pearl, I. A., McCoy, J. F. "Vanillic Acid Esters as Food Preservatives." *Food Inds.* **17**, (12), 1458 (1945).
5. Roblin, R. O., Jr. "Metabolite Antagonists." *Chem. Revs.* **38**, 265 (1946).
6. Seevers, M. H., Shideman, F. E., Woods, L. A., Weeks, J. R., and Kruse, W. T. "Dehydroacetic Acid (DHA) II. General Pharmacology and Mechanism of Action." *J. Pharmacol. Exptl. Therap.* (In press).
7. Shideman, F. E., Woods, L. A., and Seevers, M. H. "Dehydroacetic Acid (DHA) IV. Detoxication and Effects on Renal Function." *J. Pharmacol. Exptl. Therap.* (In press).
8. Spencer, H. C., Rowe, V. K., and McCollister, D. D. "Dehydroacetic Acid I. Toxicology." *J. Pharmacol. Exptl. Therap.* (In press).
9. Tanner, F. W., 1944. "The Microbiology of Foods." Garrard Press, Champaign, Illinois.
10. Whelton, R., Phaff, H. J., Mrak, E. M., and Fisher, C. D. "Control of Microbiological Food Spoilage by Fumigation with Epoxides." *Food Inds.* **18**, (1), 23-5 (1946).
11. Wolf, P. A., and Westveer, W. M. "The Antimicrobial Activity of Several Substituted Pyrones." *Arch. Biochem.* (In press).
12. Woods, L. A., Shideman, F. E., Seevers, M. H., Weeks, J. R., and Kruse, W. T. "Dehydroacetic Acid (DHA) III. Estimation, Absorption and Distribution." *J. Pharmacol. Exptl. Therap.* (In press).

A Use of Ascorbic Acid in Frozen Homogenized Milk

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(Received for publication, February 9, 1950)

The effect of varying additions of ascorbic acid to milk prior to freezing and storage in the frozen state indicates that resistance to oxidation increases with increased additions of ascorbic acid. As a practical procedure, the addition of 6 grams per 100 lbs. of milk is recommended. Apparently, addition of ascorbic acid was without effect on the physical properties of the milk and had no direct effect on flavor of the fresh milk.

Introduction

The development of an oxidized flavor in frozen homogenized milk during storage results in a product of poor quality. This laboratory, for sometime, has been looking for a method of eliminating the oxidized flavor defect, as it is believed that consumer acceptance would then be increased for this product. In line with this program, an investigation was made to determine whether or not added crystalline vitamin C (ascorbic acid), introduced in the milk before freezing as an antioxidant or oxygen acceptor, would retard the development of oxidized flavor during shipment and storage of the frozen product. The results of this investigation demonstrate that increasing the natural vitamin C content of the milk has a favorable effect on frozen milk quality during storage.

It has been shown from earlier studies *(1, 5, 7, 8, 10)* that freezing and storage temperatures affect the physical character of frozen milk. Investigators *(2, 3, 9)* have shown that when homogenized milk was frozen, the solid components tend to concentrate in the lower portion of the sample. Freezing and storage temperatures did not seem to affect its general chemical composition. Later studies *(6, 4, 11)* have shown the effectiveness of added ascorbic acid in retarding the development of oxidized flavor. The literature does not yield information on the retardation of oxidized flavors in frozen homogenized milk.

In the present study, the use of added ascorbic acid in frozen homogenized milk was also considered as a source of the vitamin in the daily diet, in addition to its possible antioxidant value. The vitamin retention during storage was found to be good particularly at the higher concentrations. Simulated shipping conditions had no adverse effects on vitamin content. In general the results show that added Vitamin C is beneficial in frozen homogenized milk.

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Procedure

The experimental work described in this report includes tests on what is believed to be the first commercial scale application of added Vitamin C to frozen milk. Taste panels and assays on the milk were conducted by this laboratory. Samples were also shipped in dry ice to a large eastern commercial laboratory for evaluation. These cross country shipments are somewhat similar to those which might occur in the general handling of the frozen product.

Five lots of fresh milk to be frozen were set up as follows:

Lot No. 1. Control, nothing added to original milk.

Lot No. 2. 1.5 grams of ascorbic acid added per 100 pounds of milk.

Lot No. 3. 3.0 grams of ascorbic acid added per 100 pounds of milk.

Lot No. 4. 6.0 grams of ascorbic acid added per 100 pounds of milk.

Lot No. 5. 12.0 grams of ascorbic acid added per 100 pounds of milk.

The method used to incorporate the ascorbic acid into the milk was as follows: A tank holding 6000 pounds of raw milk was used for the entire test. A portion of the milk was first run through the normal processing system and served as the control sample (Lot No. 1). The remaining milk in the tank was re-measured and ascorbic acid [b] was added as described for Lot No. 2. A portion of this milk then was run through the processing system and representative samples were drawn and labeled (Lot No. 2). After again re-measuring, more ascorbic acid was added to conform with Lot No. 3. As this was being commercially processed, representative samples (Lot No. 3) were taken. Samples (Lot No. 4) containing 6.0 grams of added ascorbic acid per 100 pounds of milk were drawn off after being commercially processed and to this volume was added enough ascorbic acid to make a total addition of 12.0 grams per 100 pounds of milk as the final experimental variable (Lot No. 5).[c]

All samples were bottled in commercial wax lined "Pure-Pak" paper cartons and were prepared and handled according to regular approved commercial practice. The milk was pasteurized in a Creamery Package Type pasteurizer for 15.8 seconds, at 164° F. (75° C.); homogenized in a Creamery Package homogenizer at 138-140° F. (58-60° C.) under 1700 pounds pressure and cooled to 38° F. (3° C.) before being filled into quart containers. All equipment used was such as not to be a cause of oxidation in the milk.

Samples were taken to Sixth Army Area Food Laboratory where they were stored in an ice cream style, deep freeze unit. The normal temperature of the unit was 0° F. (—17.8° C.) rising to plus 20° F. (—7° C.) by the time all the samples were stored. All samples were frozen solid in 36 hours and were held at 0° F. (—17.8° C.) plus or minus 2° F. (—16.7° C.) during the storage period.

The taste panels were conducted as follows: The samples were removed from deep freeze unit 24-26 hours prior to panel. They were allowed to thaw at room temperature 68-70° F. (19-20° C.) for 8 hours. Samples were then placed in a home style refrigerator at 40° F. (14° C.) for 15-17 hours. About one hour before the taste panel was to take place the samples were removed from refrigerator and emptied into 2 liter glass beakers. The members of the taste panel judged the samples on color, odor, taste and texture. All information relative to treatment received by samples was withheld from members of taste panel until their judgments had been recorded and turned over to a non-participating chairman.

The investigation was initiated on 24 June 1948 and the first taste panel was held to judge the flavor of thawed product on 24 July 1948 following a month of frozen storage. These results are summarized in Table 1.

TABLE 1

Flavor Evaluation of Frozen Homogenized Milk After 30 Days of Storage

Sample Number	Added Ascorbic Acid per 100 lbs. of Milk	Taste and Flavor
	Grams	
1	None (control)	Strong, oxidized
2	1.5	Oxidized, not as severe as control
3	3.0	Very slight oxidation
4	6.0	Free of all off flavors
5	12.0	Free of all off flavors

Samples were shipped cross-country in a simulated shipping trial to a commercial laboratory to further check flavor and the stability of the added ascorbic acid. Samples were thoroughly packed in dry ice and sent by air freight. The taste panel results were identical to those mentioned above except Sample No. 3 was judged to be acceptable by the eastern laboratory. The stability data is presented in Table 2.

TABLE 2

Ascorbic Acid Stability in Frozen Homogenized Milk After 30 Days of Frozen Storage

Sample Number	pH	Added Ascorbic Acid	Found Ascorbic Acid	Found Total [d] Vitamin C	Added Ascorbic Acid Minus Found Ascorbic Acid
		Grams per 100 lbs. of Milk	*Grams per 100 lbs. of Milk*	*Grams per 100 lbs. of Milk*	*Grams*
1	6.74	Control	0.03	0.06	.....
2	6.72	1.5	0.19	1.10	1.31
3	6.72	3.0	1.85	2.51	1.15
4	6.67	6.0	4.85	5.65	1.15
5	6.63	12.0	11.30	12.70	0.70 [e]

[d] Ascorbic Acid plus dehydroascorbic acid content.

[e] Low in comparison to rest of data and from the high total Vitamin C value (12.70) it would appear that slightly more than 12.0 grams of crystalline ascorbic acid were added (perhaps nearly 13.0 grams).

The data indicates that approximately 1¼ grams of added ascorbic acid were used up in protecting the flavor of the milk during processing and storage before the examination period. Since dehydroascorbic acid, the first oxidation breakdown product of ascorbic acid, also possesses biological value, it should be noted that the total Vitamin C content (a measure of the biological activity) after processing and storage compares favor-

[b] "Roche" Ascorbic Acid, furnished by Hoffman-LaRoche, Inc., Nutley, New Jersey, was used in this study.

[c] This was done because after the samples were drawn, the remaining milk was distributed through the regular commercial outlets. The authors thought that the highest level of ascorbic acid might be tasted in the milk; however, it was not, as was later proved by taste tests made throughout the investigation.

ably with the amount of crystalline ascorbic acid added initially.

The partly filled opened containers were permitted to stand at refrigerated temperature 40° F. (14° C.) for six days and samples 3, 4, and 5 were re-assayed and tasted. This data will be found in Table 3.

The flavor of samples 4 and 5 was still good following refrigerator storage while sample No. 3 had changed and was judged inferior.

At the end of 60 days of frozen storage another taste panel was held, the results of which are given in Table 4. No assays were made at this time.

TABLE 3

Ascorbic Acid Stability In Thawed Homogenized Milk After 6 Days at 40° F. (14° C.)

Sample Number	Added Ascorbic Acid	Found Ascorbic Acid	Found Total Vitamin C
	Grams per 100 lbs. of Milk	*Grams per 100 lbs. of Milk*	*Grams per 100 lbs. of Milk*
3	3.0	0.02	0.66
4	6.0	2.38	4.00
5	12.0	8.71	11.17

TABLE 4

Flavor Evaluation of Frozen Homogenized Milk After 60 Days of Frozen Storage

Sample Number	Added Ascorbic Acid per 100 lbs. of Milk	Color	Odor	Taste and Flavor	Body
	Grams				
1	Control	Normal	Oxidized	Chalky-Marked Oxidation	Very Slight Separation
2	1.5	Normal	Normal	Slight Oxidation	Normal
3	3.0	Normal	Normal	Very Slight Oxidation	Normal
4	6.0	Normal	Normal	Normal	Normal
5	12.0	Normal	Normal	Normal	Normal

The general reaction from the results of this taste panel was that samples No. 4 and No. 5 were very good while No. 3 was not too objectionable. Sample No. 5 was judged to be richer and creamier in taste and color. Two members of taste panel found sample No. 2 to be slightly off in odor while one said it had a rancid taste. "Cappiness" was the term most often used to denote the oxidized quality.

There were eight men serving on the taste panels. However, it was only at the 60-day taste panel that all the men participated together. These eight men represented the Army, the Public Health Department, and the Commercial Dairy. They were in perfect accord with the findings. The members comprising the panel and their titles are given below:

J. S. Oein, Supt. Enumclaw Coop. Creamery, Enumclaw, Washington.
F. W. Logan, Milk Sanitarian, Seattle Health Dept., Seattle, Washington.
C. W. Betzold, Lt. Col. VC, Officer-in-Charge, Sixth Army Area Food Laboratory, Seattle, Washington.
R. E. Hale, Dairy Bacteriologist, Enumclaw Coop. Creamery, Enumclaw, Washington.
L. D. Searing, Chief Milk Sanitarian, Seattle Health Dept., Seattle, Washington.
H. R. Collins, Major VC, Food Inspector, Seattle Sub-Station (Ft. Lewis), Seattle, Washington.
R. F. Goranson, Dairy Marketing Specialist, Quartermaster Market Center, Seattle, Washington.
Dr. L. Arrigoni, Director Research, Consolidated Dairy Products Co., Seattle, Washington.

At the expiration of 90 days of frozen storage all samples were again evaluated for flavor and were assayed for vitamin content, the results of which are presented in Tables 5 and 6.

TABLE 5

Flavor Evaluation of Frozen Homogenized Milk After 90 Days of Frozen Storage

Sample Number	Added Ascorbic Acid per 100 lbs. of Milk	Taste and Flavor	Body
	Grams		
1	Control	Strong Oxidized	Separation
2	1.5	Oxidized Slightly less than control	Separation
3	3.0	Very Slightly Oxidized	Separation
4	6.0	Normal—No off Flavors	Separation
5	12.0	Normal—No off Flavors	Separation

TABLE 6

Ascorbic Acid Stability in Frozen Homogenized Milk After 90 Days of Frozen Storage

Sample Number	pH	Added Ascorbic Acid	Found Ascorbic Acid	Found Total Vitamin C
		Grams per 100 lbs. of Milk	*Grams per 100 lbs. of Milk*	*Grams per 100 lbs. of Milk*
1	6.72	Control	0.0	0.37
2	6.69	1.5	1.06	1.32
3	6.69	3.0	1.61	2.25
4	6.68	6.0	4.14	5.12
5	6.62	12.0	11.30	12.10

Samples No. 5, No. 4 and No. 3 were selected in that order of decreasing preference. Upon thawing all samples separated and no longer appeared as an homogeneous emulsion. It would definitely seem that there is little relationship between the physical instability of frozen milk after prolonged storage and flavor breakdown. As there was little indication of separation at the end of the 60 day storage period, the separation of the samples as noted after 90 days was not wholly anticipated. This phenomenon usually occurred, from past experience, around 45 days of storage. Therefore, with unwarranted optimism, it was thought that Vitamin C might also be acting to stabilize milk and thus prevent physical separation.

At the 90 day storage mark samples were shipped by air-freight to a commercial laboratory on the East Coast. Here again the purpose was to check results and to simulate actual shipping conditions. All samples were packed in dry ice and delivered to the East Coast in approximately 30 hours. Taste panel results were identical except sample No. 3 was declared to be not oxidized but not as good as sample No. 5 by the eastern laboratory staff. The assay data is similar to that previously presented.

After this longer period of frozen storage, partly filled opened containers of thawed homogenized milk were permitted to stand at refrigerated temperature to obtain further data on vitamin stability. These data were recorded in Table 7. There was little change in the total

TABLE 7

Ascorbic Acid Stability in Thawed Homogenized Milk After 3 Days at 40° F. (14° C.)

Sample Number	Added Ascorbic Acid	Found Ascorbic Acid	Found Total Vitamin C
	Grams per 100 lbs. of Milk	*Grams per 100 lbs. of Milk*	*Grams per 100 lbs. of Milk*
1	Control	0.0	0.49
2	1.5	0.37	1.49
3	3.0	1.01	2.33
4	6.0	3.06	4.85
5	12.0	11.2	12.80

Vitamin C content of these milks during refrigerator storage.

Summary

From the results of this investigation, as shown by taste panel evaluation, the development of oxidized flavor found in frozen homogenized milk can be retarded by the addition of small amounts of crystalline ascorbic acid before freezing. As as antioxidant or oxygen acceptor, added ascorbic acid therefore appears to be quite beneficial in frozen milk.

It is the opinion of the authors that 6 grams of added ascorbic acid per 100 pounds of milk produced optimum antioxidant value as well as serving as a satisfactory level for enabling milk to become a good source of the vitamin as a dietary supplement. As evidenced by the assay data after 30 and 90 days of storage, the Vitamin C retention was quite good. Milk fortified to the 6 gram level contains approximately 128 milligrams of Vitamin C per quart which is an average of 32 milligrams per average serving (8 fluid ounces). After 3 months of storage it still yielded about 27 milligrams of Vitamin C per average serving. These figures approximate the daily minimum adult requirement for Vitamin C.

Shipment of samples sent across the country, which were found upon arrival to compare closely in flavor with samples examined near the point of preparation, indicate that no adverse effect is caused by the shipment of ascorbic acid treated milk if properly handled and stored.

An extensive field test is now being conducted using 6 grams of ascorbic acid per 100 pound of milk as recommended from the results obtained herein. A small scale commercial investigation is also being conducted using ascorbic acid in combination with a stabilizer in the hope of eliminating both oxidation and physical separation of frozen milk. These studies will add to the commercial application of the results presented in this report.

Thanks are due to Mr. W. F. Alexander of Hoffman-LaRoche Co., Inc., and to Mr. R. Wilson of Kristoferson's Dairy, Seattle, Washington for their aid and guidance in making this investigation.

LITERATURE CITED

1. Babcock, C. J., Roerig, R. N., Stabile, J. N., Dunlap, W. A., and Randall, R. Frozen homogenized milk, I. Effect of freezing and storage temperatures on the physical characteristics of homogenized milk. *J. Dairy Science*, **29**, 699 (1946).
2. Babcock, C. J., Roerig, R. N., Stabile, J. N., Dunlap, W. A., and Randall, R. Frozen homogenized milk, II. Effects of freezing and storage temperatures on the chemical and bacteriological properties of homogenized milk. *J. Dairy Science*, **30**, 49 (1947).
3. Babcock, C. J., Stabile, J. N., Randall, R., and Windham, E. S. Frozen homogenized milk, III. Stability of milk solids distribution in frozen homogenized milk. *J. Dairy Science*, **30**, 733 (1947).
4. Bell, R. W. Retention of ascorbic acid, changes in oxidation potential and the prevention of an oxidized flavor during preservation of milk. *J. Dairy Science*, **31**, 11 (Nov. 1948).
5. Civtl, J. Einfluss des Gefrierens auf einige Bestandandteik und Eiganschaften der Milch. *Milchw. Forsch*, **12**, 409 (1931).
6. Vitamin C retards development of oxidized flavor in fresh milk. *Report*, Chief of Bur. Dairy Ind., Research Adm., Sept. 1, 1947, p. 23.
7. Roadhouse, C. L., and Henderson, J. L. How quick freezing affects keeping quality of milk. *Food Ind.*, **12**, 54 (1940).
8. Thurston, L. M., Brown, W. C., and Dustman, R. B. Oxidized flavor in milk. *J. Dairy Science*, **19**, 671 (1936).
9. Trout, G. M. The freezing and thawing of milk homogenized at various pressures. *J. Dairy Science*, **24**, 277 (1935).
10. Webb, B. H., and Hall, S. A. Some physical effetts of freezing upon mlik and cream. *J. Dairy Science*, **18**, 275 (1935).
11. Weinstein, B., Loewenstein, M., and Olson, H. C. The use of ascorbic acid in controlling oxidized flavor in milk. *Milk Plant Monthly*, **37**, (10) 116 (1948).

Industrial and Legal Viewpoints

Marine Transportation of Perishable Food Products in Refrigerated Ships[a]

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The economic aspects of shipboard transportation of refrigerated cargoes; proper design, safeguards, methods of applying refrigeration and stowage of low temperature, frozen, and chilled cargo are discussed. Refrigerated capacity currently available from U. S. steamship operators is reported.

Refrigerated cargo vessels provide a means of transporting commodities under refrigeration. It is imperative that the cargo be received and loaded aboard ship at the proper degree of frozen or precooled temperature. Economic considerations make it desirable that refrigerated ships be loaded or discharged in the quickest possible time, using mechanical loading and unloading equipment to permit the greatest possible number of ton miles per vessel being obtained. A loss of 25 to 30 percent in cargo carrying capacity usually results in the refrigerated ship due to the space occupied by insulation and refrigeration equipment.

Compensation for the additional capital investment in a refrigerated ship is gained through higher freight rates. There are instances in intercoastal and coastwise transportation where the benefits of the better controlled refrigeration available in a ship, as compared to the refrigerated railway car, are not attractive to the shipper due to prevailing railroad freight rates for this class of transportation.

A refrigerated ship should be specially designed with hull structure suitable to receive insulation; with moderate deck heights and with ample forethought to the location of the refrigerating machinery. Our merchant marine is spotted with examples of inferior design that prove to be costly to operate and maintain. However, in the international view, our American refrigerated tonnage surpasses that of other nations in respect to savings in space and weight; two very important items.

Today's refrigerated space in merchant ships is available with cooling supplied by direct expansion of the refrigerant in the cooling coils or a recirculated secondary refrigerant; more commonly calcium chloride brine. It is the writer's belief that for ships having greater than one hundred thousand (100,000) cubic feet of refrigerated cargo space, the cooling should be carried out with a secondary refrigerant such as calcium chloride brine, while for less than one hundred thousand (100,000) cubic feet, the cooling may be either with the primary refrigerant or a secondary refrigerant.

Automatic temperature control has been applied in some recent installations. Operators are desirous of having their refrigerating system automatically controlled, with reliable controls that will function without undue servicing. In many instances these automatic controls prove to be too complex for the operating personnel on board the vessel. When they become inoperative, they are by-passed or otherwise dispensed with in favor of hand control to maintain the cargo at optimum condition.

Some of the safety precautions exercised to preserve and protect perishable food products that are shipped in refrigerated ships are: First, during design and planning, the proposed installation must receive approval from the Classification Society, such as American Bureau of Shipping or Lloyd's, and the United States Coast Guard. The Classification Society approves the adequacy of the proposed installation and U. S. Coast Guard the safety. Secondly, following installation and at periodic intervals throughout the life of the ship they require the refrigeration equipment and insulation to be tested and to pass inspection in accordance with their rules.

In addition to spare units, a large complement of spare parts is required to be carried as well as spare drums of refrigerant. This is all additional weight, where weight is not desired, in order to guarantee safe delivery at port of discharge of perishable refrigerated cargo.

All of this is necessary for the refrigerated ship because unlike the refrigerated railway car, truck or aircraft, it may have refrigerated cargo on board for a month or longer with only the resourcefulness of the operating personnel to effect any necessary repairs while at sea.

The only research carried out in this country to effect the best means of uniformly cooling a cargo hold has been done by private shipping industry. Great Britain has done much research ashore in models of ship holds in an effort to determine the most efficient and effective manner of cooling ship holds. The results of this latter investigation serve only to confirm that our method, most generally practiced here, of passing the air vertically upward through the cargo stow produces the most uniform results.

Dehydration of all classes of refrigerated products is a problem, whether they be quick frozen low temperature products, maximum temperature —10° F.; frozen products, maximum temperature +15° F.; or chilled

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products such as fresh fruits and vegetables carried at a temperature of +32° F. or higher.

Since many products are sold by weight, any shrinkage through dehydration is directly reflected in the dollar sales value. To maintain refrigeration effectively we must have a cooling source where the temperature is lower than the product being maintained. Whenever we have this condition prevailing, as we most generally do in any refrigeration process, we establish a difference in vapor pressure between that of the refrigerated product and the vapor pressure existing at the heat absorbing surface of sufficient gradient to cause water vapor to travel from the region of higher vapor pressure, the product, to the region of lower vapor pressure which exists at the cooling coils. Here water vapor is condensed to form either water or frost depending upon the temperature of the cooling coils. The exception to this, is the case where products may be contained in sealed vapor tight containers.

In practice, "live cargoes" (fruits and vegetables) are respiring and in the process evolve heat and gases. These gases contain water vapor which is picked up by the air and conveyed to the cooling coils where the water vapor is condensed and drained off through the cooler pan scuppers. The ability of the air to transport this moisture is enhanced by the fact that the dry bulb temperature is elevated due to the heat gained by the air in absorbing heat leakage and product heat. Thus the relative humidity of the air is lowered and its ability to hold more moisture is increased.

The practical answer to this very important point is to have a low mean temperature difference between the air and refrigerant within the cooling coils, and to maintain a sufficiently high rate of air circulation to permit cooling of product with a low range in dry bulb air temperature. This is important though rarely understood, because unless this gradient is kept small by high rates of air circulation, we have the elevated dry bulb temperature with a lowering of relative humidity. A low velocity air through the stowed cargo is also desired to minimize loss of weight. A high rate of air circulation does not necessarily mean one will have a high velocity through the stowed cargo unless the design intends such to be the case. Where the design is such that the air is distributed to pass over the largest area of stowed cargo within the hold, such as vertically upward from deck to deckhead, high rates of air circulation should be employed to minimize the temperature gradient and change in relative humidity of the air in passing through the cargo.

Cargoes of uniformly cased products whether for quick frozen low temperature, frozen or chilled temperature transportation must be properly dunnaged with material to separate the cases in order that air, whether forced or by convection currents, will not be seriously impeded in movement through the stow. In the case of some products which are irregular in shape, such as sides of beef, or cases with a bulge on one side, stowage can generally be arranged for adequate air circulation without dunnage.

In the past it was common practice to use plain pipe coil forced air coolers, with the coils spaced on about four (4) inch centers, for operation below the freezing point. It was believed then that finned pipe air coolers would be troublesome due to accumulation of ice or frost which would retard heat transfer and air passage across the cooler. Experience has shown that the finned pipe air cooler surpasses the plain pipe cooler for operation in any of the three previously mentioned temperature zones. With the greater amount of total surface available for cooling on the finned coil, the resultant mean temperature difference is less and since the amount of moisture pick-up is a function of mean temperature difference, less moisture is condensed from the air. Moisture that is condensed has a greater surface area on which to accumulate, resulting in a thinner layer of ice or frost when operating below the freezing point. This type of cooling coil can also be defrosted quicker than the plain pipe coolers, particularly with warm brine where brine is used as the secondary refrigerant.

The refrigerated transportation of foods in a controlled atmosphere of gas has not been attempted in this country as there has been little or no need for it.

The English, who are dependent upon Australia and New Zealand to a large extent for their fresh meat supply, have been transporting cargoes of chilled fresh meat in an atmosphere containing about ten (10) percent carbon dioxide. Reports indicate that meats shipped in this manner reach their destination appearing fresher, with more bloom and greatly retarded mould growth. Some shipments of apples have also been made in this manner. The difficulty and problem of maintaining a controlled atmosphere of gas in a refrigerated hold is in the inability to retain the gas within the insulated compartment due to movement of the ship's structure and changes in barometric pressure.

Of 23,000,000 cubic feet of refrigerated cargo space in United States vessels which are capable of transporting 270,000 long tons of perishable food products at optimum temperatures, the classification in respect to total tonnage available in ships of varying total refrigerated volumes is as follows:

SHIPS REFRIGERATED VOLUME IN CUBIC FEET

	300,000 to 350,000	200,000 to 250,000	150,000 to 200,000	100,000 to 150,000	40,000 to 100,000	Less Than 40,000
Space available..	8,500,000	425,000	5,250,000	4,000,000	4,500,000	1,000,000
Cap. long tons.....	100,000	5,000	62,000	47,000	53,000	12,000